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ABSTRACT

This proceedings contains the texts of 14 science education research studies which were presented at the 1983 Western Australia Science Education Conference. They include: "Students' Understanding of Chemical Equilibrium: A Report of Research in Progress" (Patrick J. Garnett, Mark W. Hackling); "Measuring the Learning Environment in Elementary and Middle Science Classrooms" (Trevor W. Lacy); "The Effect of Inservice Training on Teacher Attitudes and Primary School Science Classroom Climates--An Interim Report" (Pauline Hutchinson); "Why Teach Science?" (Leonie J. Rennie), focusing on primary school science instruction; "Identifying Characteristics of Primary Science Teaching Styles" (L. N. McKenna); "Time Available for Teaching: A Survey in Four West Australian Schools" (M. C. Crosbie); "Primary Science Today" (John D. Rowe); "How Well Do Standard Piagetian Protocols Assess Aboriginal Children's Conservation Behavior?" (David F. Treagust, Ross Hastie); "Enhancing Student Engagement in Upper Primary and Lower Secondary Science Activities" (Kenneth G. Tobin); "Beyond the Keller Plan" (Phillip Jennings), reviewing application of the Keller scheme in college physics; "John Forrest National Park as an Ecological Study Area" (Bill Foulds, Judy Parsons); "Priorities for Computer Education in W.A." (M. J. O'Loughlin, J. Luca); "Techniques for Formative Evaluation of Science Curricula" (Barry J. Fraser); and "Problem Solving in Physics" (John Deacon), examining problem-solving methods and misconceptions found in student answers on the 1979 W.A. Tertiary Admissions Physics Examination. (JN)

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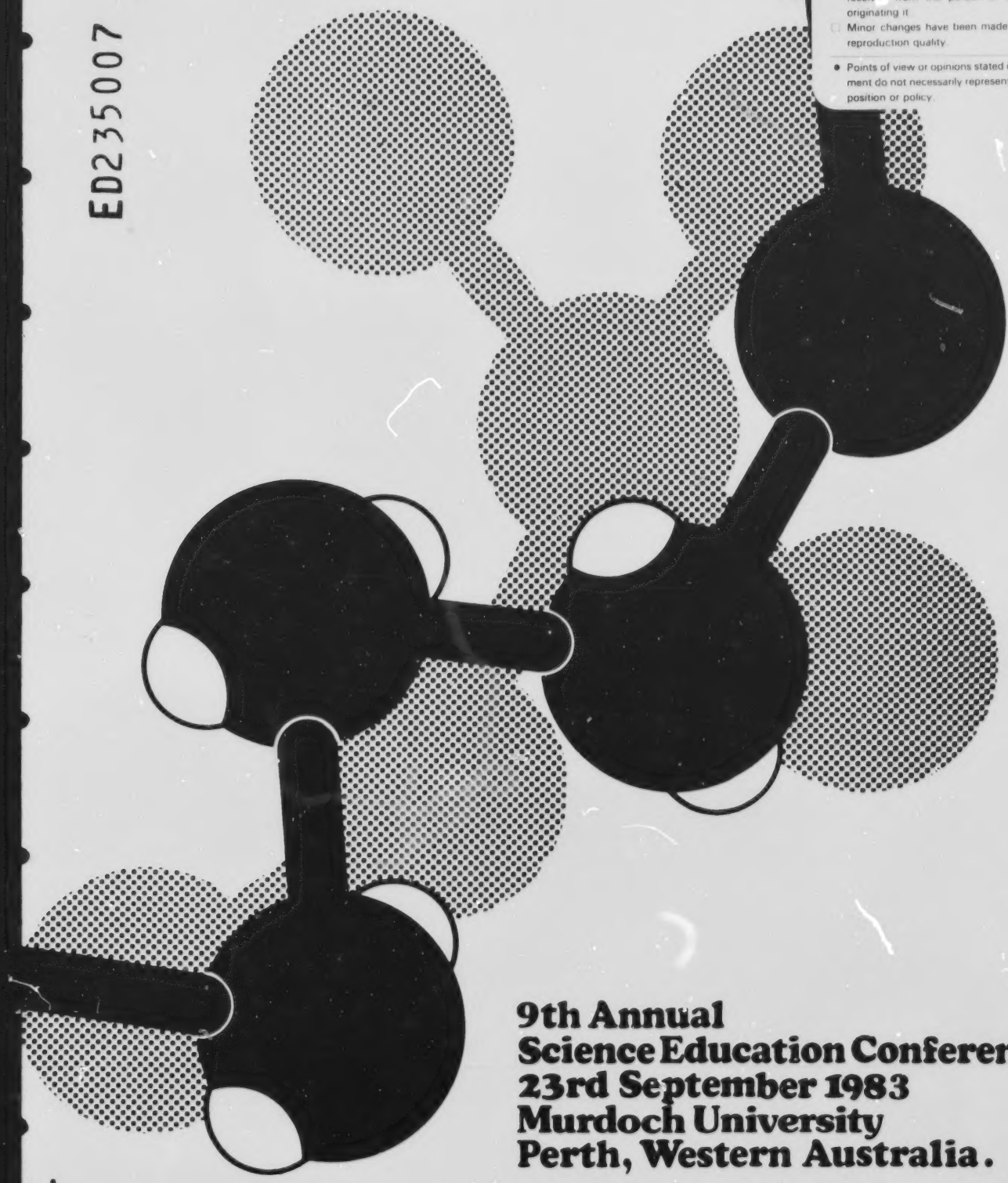

9th Annual Science Education Conference 23rd September 1983 Murdoch University Perth, Western Australia.

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(This booklet contains the text of papers presented at the 1983 conference. A copy of the complete programme is included at the back).

THE W.A. SCIENCE EDUCATION ASSOCIATION

The primary purpose of the Association is to promote dialogue among those vitally concerned with the development of science education and the training of science teachers in this state. The Science Education Association is unique. Its success depends very much upon you.

The annual conference of the W.A. Science Education Association is your opportunity to meet and converse with colleagues from other tertiary institutions and the Western Australian Education Department.

One of the most pressing problems we face in our profession is a lack of effective communication. For this reason, it is important for you to allocate time to attend and meet other science educators.

This conference was planned by the Science Education Association. The Association is a very loosely knit one, similar in nature to the Australian Science Education Research Association. Membership is open to anyone who attends the conference - your attendance will indicate your interest and involvement in science education. The informality of the organisation has proved very successful since its inception in 1975. Some of the best science educators in the country have spoken at the annual conference. The greatest success so far was the sponsoring and convening of the tenth annual Australian Science Education Research Conference in Perth in 1979.

Each year, the Association organises a one-day conference at one of the tertiary institutions. Each institution takes this responsibility in turn. So far, the conferences have been held at:

1975 - Churchlands College
1976 - Mount Lawley College
1977 - Nedlands College
1978 - Murdoch University
1979 - University of Western Australia
1980 - W.A. Institute of Technology
1981 - Claremont College
1982 - W.A. Education Department
1983 - Murdoch University

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STUDENTS' UNDERSTANDING OF CHEMICAL EQUILIBRIUM

Patrick J. Garnett and Mark W. Hackling

Western Australian College of Advanced Education

INTRODUCTION

The science education literature of the 1980's contains numerous studies of students' understanding of scientific phenomena. These studies have revealed that students bring to instruction, views and explanations of natural phenomena that differ from the views held by scientists (Osborne, 1982). Such views of the world held by children are not simply isolated ideas but form conceptual structures which provide a coherent understanding of the world from the child's point of view (Gilbert, Osborne and Fensham, 1982).

Driver (1982) has described the re-emergence of constructivist psychology which assumes the existence of the learner's conceptual schemes and the active application of these in responding to, and making sense of new situations. Pope and Gilbert (1983) argued that a "cultural transmission" approach to teaching dominates science education and that this approach has neglected the role of students' personal experiences in their construction of knowledge. They suggest that the constructivist psychology of Kelly (1955) is a more appropriate framework for viewing science learning. Similarly Osborne and Wittrock (1983) have advocated the adoption of the generative learning model which describes learning as a process of constructing meaning which is strongly influenced by students' prior conceptions. Learning in science should therefore be seen as a restructuring of existing ideas rather than merely adding information to existing knowledge. Gilbert, Osborne and Fensham

(1982) have described the interaction of the child's view and that presented by the teacher and have outlined the learning outcomes which may result, a common outcome being the emergence of some misconception following instruction. Information regarding the preconceptions students bring to instruction and the misconceptions held following instruction is essential for the improvement of instruction.

Within the domain of chemistry surveys have revealed that the topics of chemical equilibrium, the mole, oxidation-reduction and reaction stoichiometry pose learners most difficulty; of these topics chemical equilibrium was rated as the most difficult for students to comprehend (Finley, Stewart and Yarroch, 1982). This paper describes misconceptions concerning chemical equilibrium held by Year 12 chemistry students following instruction.

Two research questions were addressed in the investigation:

1. Which concepts and propositions are necessary for Year 12 students to comprehend chemical equilibrium and the application of Le Chatelier's Principle?
2. Which of those concepts and propositions are most frequently, not understood or misunderstood and therefore limit students' understanding of the topic?

METHOD

Identification of Equilibrium Concepts and Propositions

Teaching programmes, textbooks and syllabus statements were analysed to identify the sequence of propositions which would lead to an understanding of chemical equilibrium and the application of Le Chatelier's Principle. The propositions (see Appendix 1) were cross-validated as to their relevance for an understanding of equilibrium by tertiary lecturers in chemistry and by experienced chemistry teachers.

Instrument Development

Two pilot studies were conducted to develop and trial a partially standardized interview instrument. The content validity of the instrument was ensured by basing its construction on the previously validated list of propositions. The interview instrument consisted of a series of probing questions which required students to apply their understanding of equilibrium to explain and graph changes in concentrations and reaction rates for a novel chemical reaction. The subjects were individually interviewed; each interview was tape recorded with the permission of the student.

Subjects

A modified stratified - random sampling technique was used to select a sample of thirty Year 12 students; one student was selected from the upper, middle and bottom thirds of each of ten different chemistry classes. The subjects were drawn from two independent schools and from five State schools in the Perth metropolitan area.

Analysis of Data

The component sub-ideas of each proposition probed by the interview were identified and listed. The tapes were replayed and each of the students' responses was coded for understanding as comprehension, recall, lack of knowledge or misunderstanding of the sub-idea. The tapes were coded by the two investigators working together to enhance scorer reliability.

RESULTS

Table 1 contains a list of propositions for which common misconceptions were identified. These have been grouped under the general headings initial establishment of equilibrium, characteristics of chemical equilibrium, and changing equilibrium conditions.

Table 1

The Most Common Misconceptions of Chemical Equilibrium Propositions Held By Year 12 Students (N=30).

Proposition[a]	Misconception	Percentage of Students
APPROACH TO EQUILIBRIUM		
5(a)	Forward reaction rate increases as the reaction gets going.	23%
5(b)	Reverse reaction rate is the same as the forward rate.	17%
CHARACTERISTICS OF CHEMICAL EQUILIBRIUM		
3	There is a simple arithmetical relationship between the concentrations of reactants and products.	50%
CHANGING EQUILIBRIUM CONDITIONS		
Effect on concentrations		
8(a)	After the [NO] is instantaneously increased the [NO] remains the same.	17%
Initial effects on rates of reactions		
10	When the [NO] is increased the rate of the reverse reaction is decreased.	43%
15	When the temperature is increased the rate of the forward reactions is decreased.	57%
21	When the volume is decreased the rate of the reverse reaction is decreased.	63%
Rates of reactions when equilibrium is re-established		
11(b) 16(b) 22(b)	When equilibrium is re-established the rates of the forward and reverse reactions will be equal to those at the initial equilibrium.	40% 27% 27%
Effect on equilibrium constant		
12	When [NO] is added and equilibrium is re-established the equilibrium constant is greater than under the initial conditions.	20%
23	When the volume is decreased and equilibrium is re-established the equilibrium constant is greater than under the initial conditions.	30%
17	When the temperature is increased and equilibrium is re-established the equilibrium constant is the same as under the initial conditions.	27%
Effect of a catalyst		
24	A catalyst can effect the rates of the forward and reverse reactions differently.	27%

Note:

a These numbers refer to the propositions listed in Appendix 1.

DISCUSSION

Approach to Equilibrium

Students generally had a qualitative understanding of the way in which the concentrations of reactants and products changed as a reaction approached equilibrium. Most students, however, were unable to explain the way in which the rates of the forward and reverse reactions changed during the approach to equilibrium (proposition 5). The most common misconception regarding the rate of the forward reaction was that the rate increased as a function of time - "as the reaction got going." For the reverse reaction the most common misconception was that the rate changed in the same way as the rate of the forward reaction. Some students seemed unable to consider the forward and reverse reactions separately. Others thought that the forward reaction went to completion before the reverse reaction commenced.

Characteristics of Chemical Equilibrium

Most students were able to explain that once equilibrium was achieved the concentrations of the species remained constant and that the rates of the forward and reverse reactions were equal. However a common misconception among students interviewed was that there was a simple arithmetic expression relating the concentrations of reactants and products. Fifty percent of students interviewed had a misconception of this nature, the most common being that the concentrations of the reactants equalled the concentrations of the products or that the concentrations of NO and NOCl were equal. The latter misconception was clearly based on a consideration of the coefficients in the chemical equation.

Changing Equilibrium Conditions

Effect on concentrations

Predictions concerning the effects of various changes to the equilibrium system on the concentrations of reactants and products were reasonably accurate. One exception to this occurred when students were asked to predict the effect of adding more NO to the equilibrium system. Only 60% of students were able to predict that the NO concentration would decrease below its adjusted value and only 40% predicted that the final NO concentration would be between the initial equilibrium and adjusted values. The most common misconception was that the NO concentration would remain at its adjusted value but the Cl_2 concentration would decrease and NOCl concentration increase to compensate for this.

Initial effects on rates of reactions.

During the interview students were asked to explain what effect changing the various factors (increasing the concentration of NO, increasing temperature, and decreasing the volume of the system) would have on the rates of the forward and reverse reactions. A very common misconception among students was that the rate of the favoured reaction was increased but the other reaction rate was decreased. For example, when the temperature was increased, 57% of students believed that the rate of the reverse reaction was increased but the rate of the forward reaction was decreased.

Similar misconceptions occurred for propositions 10 and 21. These misconceptions were clearly caused by students confusing the effects of changes in the conditions on the relative amounts of reactants and products, with the effects on the rates of the forward and reverse processes. When these misconceptions were probed in the interview, students typically responded that the rate in one direction would be increased and in the reverse direction decreased in order to accomodate the changes predicted from the use of Le Chatelier's Principle.

Rates of reactions when equilibrium is re-established.

Following changes made to the equilibrium system most students understood that when equilibrium was re-established the rates of the forward and reverse reactions would again be equal. Very few students, however, could compare the rates of the reactions when equilibrium was re-established with those at the initial equilibrium. The most common misconception was that the rates when equilibrium was re-established would be the same as at the initial equilibrium. This misconception was held by 46%, 27% and 27% of students for propositions 11(b), 16(b) and 22(b) respectively.

Effect on the equilibrium constant.

After changes had been made to the conditions affecting equilibrium systems only a small proportion of students were able to compare the equilibrium constant under the new conditions with that under the previous conditions.

For proposition 12, 20% of students believed that the equilibrium constant was greater after increasing the concentration of NO because this produced an increase in the NOCl concentration. Similarly for proposition 23, 30% of students concluded that decreasing the volume of the system would increase the equilibrium constant. Again this indicates that the students are focussing on changes in the NOCl concentration. They are not considering the changes in the concentrations of the other species involved.

When the temperature of the system was increased the equilibrium constant for the considered reaction is decreased. Twenty seven percent of students considered the equilibrium constant was unchanged. Probably such students have learnt that the equilibrium constant has a fixed value and are applying that idea to situations where it is not appropriate.

Effect of a Catalyst.

The questions relating to the addition of a catalyst were generally answered reasonably well. A surprisingly common misconception, however, was the notion that the rates of the forward and reverse reactions could be affected differently by the addition of a catalyst. This misconception was held by 27% of students.

CONCLUSIONS

The students interviewed had a poor understanding of the quantitative aspects of chemical equilibrium, and of reaction rates in relation to the establishment of and changes to equilibrium. The most significant misconceptions that were revealed by this study were:

1. That a simple arithmetical relationship existed between the concentrations of reactants and products at equilibrium (e.g. concentrations of reactants equalled concentrations of products).
2. That when a system is at chemical equilibrium and a change is made in the conditions, the rate of the favoured reaction is increased but the rate of the reverse reaction is decreased (e.g. when the temperature is increased the rate of the endothermic reaction is increased but the rate of the exothermic reaction is decreased.)
3. A catalyst can effect the rates of the forward and reverse reactions differently.

Further reseach is needed to assess the possible origin of these misconceptions. The constructivist psychological frameworks presented by Hope and Gilbert (1983) and Osborne and Wittrock (1983) indicate that a study of the preconceptions held by students, before they are exposed to instruction, may be fruitful in explaining the origin of these misconceptions.

Although calculations using equilibrium constants are not part of the current Tertiary Admissions Examination Syllabus, there may be a case for including a small amount of work on quantitative aspects of chemical equilibrium. In this way students would gain a clearer picture of the relationships between the concentrations of reactants and products in equilibrium systems.

High priority must also be given to the development of a pencil and paper diagnostic test that can be used by teachers to identify students who have these misconceptions so that appropriate remedial action can be taken.

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APPENDIX 1

PROPOSITIONS CONCERNING CHEMICAL EQUILIBRIUM

Consider the reaction

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g) + \text{heat}$$

If some NO and Cl_2 are mixed in a closed system...

CHARACTERISTICS OF CHEMICAL EQUILIBRIUM

1. Approaching equilibrium the
   (a) [NOCl] increases.
   (b) [NO] decreases.
   (c) $[Cl_2]$ decreases.

2. After equilibrium has been established the concentrations of all the species present remain constant with time.

3. At equilibrium the concentrations of reactants and products are related by the equilibrium law

$$K = \frac{[NOCl]^2}{[NO]^2[Cl_2]}$$

4. A large equilibrium constant indicates that the equilibrium concentrations of products are large relative to the concentrations of reactants; a small equilibrium constant indicates that the equilibrium concentrations of products are small relative to the concentrations of reactants.

5. Approaching equilibrium the rate of the
   (a) forward reaction decreases as the concentrations of reactants decrease.
   (b) reverse reaction
      (i) is initially zero
      (ii) increases as the concentrations of products increase.

6. At equilibrium the forward and reverse reactions
   (a) continue to occur
   (b) have equal rates

CHANGING EQUILIBRIUM CONDITIONS

7. Le Chatelier's Principle - If a system is at chemical equilibrium, and some change is made in the conditions, the system adjusts to re-establish equilibrium in such a way as to partially counteract the imposed change.

Changing the concentration of one of the reacting species

After equilibrium has been achieved the [NO] is instantaneously increased (but the volume remains unchanged).

8. When equilibrium is re-established the
   (a) [NO] will be
      (i) less than its adjusted value
      (ii) higher than its initial equilibrium value
   (b) $[Cl_2]$ will be less than its initial equilibrium value
   (c) [NOCl] will be greater than its initial equilibrium value.

9. The concentrations change in such a way that they partially counteract the imposed change (an increase in [NO]). Thus the system adjusts to reduce the [NO]; the [NO] and $[Cl_2]$ decrease and the [NOCl] increases.

10. When the [NO] is increased the rate of the
   (a) forward reaction will instantaneously increase
   (b) reverse reaction will
      (i) be initially unchanged
      (ii) gradually increase.

11. When equilibrium is re-established the rate of the
   (a) forward and reverse reactions will be equal.
   (b) forward and reverse reactions will be greater than at the initial equilibrium.

12. When equilibrium is re-established the equilibrium constant is the same as under the initial conditions.

Changing the temperature of the system

After equilibrium has been achieved the temperature is instantaneously increased (but the volume remains unchanged).

13. When equilibrium is re-established the
   (a) [NO] will be greater than its initial equilibrium value
   (b) $[Cl_2]$ will be greater than its initial equilibrium value
   (c) [NOCl] will be less than its initial equilibrium value

14. The concentrations change in such a way that they partially counteract the imposed change (an increase in temperature). Thus the system adjusts to favour the endothermic reaction; the [NO] and $[Cl_2]$ increase and the [NOCl] decreases.

15. When the temperature is increased the rate of the
   (a) forward reaction will increase
   (b) reverse reaction will increase
   (c) reverse reaction will be greater than the rate of the forward reaction.

16. When equilibrium is re-established the rate of the
   (a) forward and reverse reactions will be equal
   (b) forward and reverse reactions will be greater than at the initial equilibrium.

17. When equilibrium is re-established the equilibrium constant is smaller than under the initial conditions.

Changing the volume of the system (or the pressure on the system)

After equilibrium has been achieved the volume of the system is decreased (but the temperature remains unchanged).

18. The concentrations of all gaseous species in the system will instantaneously increase.

19. When equilibrium is re-established the
    (a) [NO] will be less than its adjusted value
    (b) [Cl_2] will be less than its adjusted value
    (c) [NOCl] will be greater than its adjusted value

20. The concentrations change in such a way that they partially counteract the imposed change (an increase in the concentration of gaseous particles). Thus the system adjusts to favour the reaction producing the smaller number of gaseous particles; the [NOCl] increases and the [NO] and [Cl_2] decrease.

21. When the volume is decreased the rate of the
    (a) forward reaction increases
    (b) reverse reaction increases
    (c) forward reaction will be greater than the rate of the reverse reaction.

22. When equilibrium is re-established the rate of the
    (a) forward and reverse reactions will be equal
    (b) forward and reverse reactions will be greater than at the initial equilibrium.

23. When equilibrium is re-established the equilibrium constant is the same as under the initial conditions.

Adding a catalayst

After equilibrium has been achieved a catalyst is added to the system.

24. The rate of the
    (a) forward reaction is increased
    (b) reverse reaction is increased
    (c) forward and reverse reactions are equal.

25. The concentrations
    (a) [NO] is unchanged
    (b) [Cl_2] is unchanged
    (c) [NOCl] is unchanged.

26. The equilibrium constant is the same as under the initial conditions.

DEVELOPMENT AND VALIDATION OF AN ELEMENTARY AND MIDDLE SCHOOL SCIENCE LEARNING ENVIRONMENT INSTRUMENT

TREVOR W. LACY

EDUCATION DEPARTMENT, WESTERN AUSTRALIA

WARRIAPENDI PRIMARY SCHOOL

REDCLIFFE AVENUE

BALGA

WA 6061.

Development and Validation of an Elementary and Middle School Science Learning Environment Instrument

INTRODUCTION

A study of classroom learning environments may involve consideration of the physical, social and psychological aspects of such environments either singularly or collectively. Reasons for initiating classroom environment studies may be numerous and varied. A fundamental desire to provide a more aesthetically pleasing and socially harmonious classroom setting in which students and teachers can work happily and cooperatively together is, in itself, a most commendable aim. On the other hand, a more complex motive may stem from a desire to promote student learning outcomes. Whatever the motivation for such studies, there is sufficient evidence to suggest that they can be both worthwhile and rewarding.

Numerous instruments have been developed to measure more general aspects of classroom learning environments. The Learning Environment Inventory (LEI) (Andersón and Walberg, 1976), the Classroom Environment Scale (CES) (Moos and Trickett, 1974) and the Individual Classroom Environment Questionnaire (ICEQ) (Rentoul and Fraser, 1979), more specifically designed for use in high schools, are representative of the instruments commonly used in classroom research. Such instruments have been found to be effective both as curriculum evaluation tools and in predictive classroom studies where intervention has been successful in changing the learning environment in order to promote student learning outcomes. Fraser (1981; 1982) provides many instances to substantiate this. However, in almost every case, the studies cited have been directly concerned with the general classroom learning environment or secondary science classrooms. To date, little attention has been specifically given to the development of instruments which will provide greater insight into the somewhat unique learning environments more suited to promote learning in elementary and middle school science classrooms. This paper describes the development and validation of the Elementary Science Learning Environment Questionnaire (ESLEQ) which may be used by teachers, classroom researchers and/or curriculum evaluators to provide measures of pupil perceptions of three aspects of the science learning environment in elementary and middle school classrooms; the role of the teacher, pupil involvement, and pupil satisfaction.

It is not uncommon for classroom learning environment instruments to involve simultaneous administration of more than one form. For example, the ICEQ consists of four parallel forms which collectively have been developed to measure actual and preferred perceptions of both students and teachers. Fraser (1982) reports numerous benefits to be derived from the use of parallel forms in order to establish a more harmonious personal-environment fit between individuals and the learning environment. The implications of this research for teaching science in elementary

and middle school science classrooms have been taken into consideration in the development of ESLEQ. Consequently, the actual version of ESLEQ is complimented by a parallel, preferred form.

RATIONALE FOR THE DEVELOPMENT OF ESLEQ

Teachers of elementary science have an ever increasing range of options available to them. The philosophical, psychological and educational foundations upon which elementary science is based have been under continual review since the 1950's. Consequently, this has led to the articulation of a comprehensive set of aims and objectives. Johnson (1983) in reporting upon recent initiatives sponsored by the National Science Foundation drew attention to many of the important characteristics of effective elementary science classrooms. Such classrooms were reported as attending to: the academic and personal needs of students; environmental and societal issues; and awareness and career education in science related fields. The programmes carried out in such classrooms were characterized by a problem-solving approach in which students were actively involved in data gathering through first-hand experiences. Successful program implementation was dependent upon all pupils having equal access to science instructional materials and the ability of teachers to structure interactions between students, supply and handle materials and demonstrate appropriate questioning strategies.

Popular elementary science curriculum resource materials, developed during the past two decades, differ considerably in the degree of emphasis that they place upon the acquisition and assimilation of knowledge, competency in process skill attainment and the development of appropriate affective characteristics. Despite these differences, all advocate a similar approach to teaching and learning science. For example, while the Science Curriculum Improvement Study (SCIS) places an emphasis on concept development and Science a Process Approach (SAPA II) highlights the desirability of process skill mastery, the Elementary Science Study (ESS) has a tendency to advocate that greater attention be given to the fostering of appropriate attitudes and interests. Although the fundamental aims of elementary school science curricula may be described as diverse, they each share a common materials centered approach to teaching and learning which contrasts markedly with the more highly formalized, content oriented, traditional practices previously advocated.

Prior to the 1960's pupils were expected to be little more than passive recipients with a propensity to recall facts while teachers imparted the knowledge contained within highly prescriptive syllabii. The "new" science curricula, however, advocate the establishment of enriched learning environments in which pupils may be directly involved with manipulating materials and in the investigation of objects, substances, phenomena and events. Such innovations have direct implications for change in the roles of both teacher and pupil.

ESLEQ compliments the materials-centered approach to teaching and learning science in elementary classrooms and can be utilized in a number of ways. For example, an analysis of pupil responses to both the actual and preferred forms will not only provide an overview of how pupils actually perceive the science learning environment but will also assist teachers in modifying existing teaching strategies and classroom procedures so as to more fully meet the needs of the class and of individual pupils. Fraser and Deer (in press) report that teacher intervention, which represents a synthesis of both actual and preferred pupil perceptions of the classroom learning environment, can result in appreciable changes within the environment. Furthermore, appropriate environmental features may significantly influence student learning outcomes. Fraser and Rentoul (1980) reported that student cognitive achievement was related to the degree of congruence between the actual classroom environment and that preferred by students. Consequently, it is with these points in mind that the ESLEQ has been developed for use in elementary and middle school science classrooms.

PROCEDURES

In the following sections the development of ESLEQ is described and details of a study designed to obtain measures of internal consistency, construct validity and discriminant validity are presented.

Development of ESLEQ

Selection of suitable items and scales and the adoption of an appropriate format to be used by pupils to record their perceptions were major considerations addressed in the development of ESLEQ. Research on social climate scales by Moos (1974) and the review by Fraser and Walberg (1981) provided guidance for selection of the initial pool of items and scales comprising ESLEQ. Laidman's (1977) study of the development of a metric for multiple response categories assisted in the preparation of the adopted pupil recording format.

Selection of suitable scales and items.

Two major considerations addressed in the selection of suitable items involved consideration of appropriate general categories and inclusion of valid and reliable items and scales from existing instruments. Firstly, the three general categories of dimensions outlined by Moos (1974) provided an initial focus for selection of items. These three categories are: (a) Relationship Dimensions which are concerned with the nature and intensity of personal relationships; (b) Personal Development Dimensions which are concerned with the basic directions along which personal growth and self-enhancement tend to occur; and, (c) Systems Maintenance and Change Dimensions which are concerned with the

extent to which the environment is orderly, clear in expectation, maintains control and is responsive to change. In order to provide an adequate and comprehensive overview of social environments, Moos (1974) implied that it is essential for each of these three general category dimensions to be measured. Secondly, items and scales reported as being both valid and reliable, were selected for ESLEQ from existing instruments.

In addition to these two criteria, guidelines for the selection of appropriate items and/or scales were consistent with a number of other requirements. Firstly, the level of reading difficulty and the time required to complete the questionnaire were such that the final version of the instrument was suitable for use by pupils from grades 4 - 8 within elementary and middle school classrooms. Secondly, items and/or scales selected were consistent with implications for teaching and learning science in materials-enriched learning environments such as those recommended in SAPA, ESS and SCIS.

Subsequently, items and scales selected for the initial version of ESLEQ were extracted from the following previously validated instruments: the Individual Classroom Environment Questionnaire (ICEQ) (Rentoul and Fraser , 1979); the My Class Inventory (MCI) (Anderson and Walberg, 1976); the Learning Environment Inventory (LEI) (Anderson and Walberg, 1976); and the Teacher Performance Assessment Instruments (TPAI) (Capie, Johnson, Anderson, Ellett and Okey, 1979). Figure 1 lists the thirty five items initially selected and provides further details regarding the source from which they were extracted as well as their relationship to Moos's general categories.

Adoption of an appropriate recording format.

An hierarchical set of five unambiguous, equal-interval stimulus phrases, to be presented as distractors, was selected from a list of twenty contained in the summated rating scale described by Laidman (1977). "Very Often", "Fairly Often", "Sometimes", "Not Very Often" and "Hardly Ever", which center on "Sometimes" as the anticipated modal response, were the equal-interval response categories chosen for ESLEQ. Fraser and Deer (in press) reported that when responding to the MCI, a small number of elementary school pupils were undecided in their responses and would have found it preferable had they been able to record undecided responses in an appropriate way. Accordingly, a further category, "I Don't Know", was added to the set of distractors. Consequently, ESLEQ respondents are provided with a choice of six distractors for each item on the questionnaire.

The original pool of items and the corresponding scales that constituted ESLEQ have been substantially modified as a result of field testing. ESLEQ consists of two versions of the questionnaire; the student actual form and the student preferred form (See Figures 2 and 3). Each of these two forms contains thirty two parallel items.

The need for modification to the initial format of ESLEQ was evident for a number of reasons. The pooling of items from a variety of sources necessitated almost immediate attention in order to provide a uniformity of language and a common readability level. Analyses performed on data obtained through trialing several versions of the instrument had implications for further modifications. These analyses are discussed later in the paper. The most significant modification resulted in the reduction of the initial five scales (see Appendix A) to only three, i.e., pupil involvement; the role of the teacher; and pupil satisfaction.

Scoring procedures.

Data collected to establish construct validity, internal consistency and discriminant validity were scored so as to conform to the following guidelines. For each item contained in ESLEQ, respondents were provided with six distractors. To register a valid response, the intention to select one of these needed to be evident. If a respondent chose not to answer or provided a multiple response for any item, such actions were interpreted as "I Don't Know" for scoring purposes. Once invalid responses had been attended to in this way, the distractors were then assigned a score from zero to five as follows: Very Often - 5; Fairly Often - 4; Sometimes - 3; Not Very Often - 2; Hardly Ever - 1; and I Don't Know - 0.

Sample used in the field testing of ESLEQ

The sample used to examine the validity and reliability of ESLEQ comprised 14 intact classes from three large suburban primary schools in Perth, Western Australia; a boys' school, a girls' school and a co-educational school. There was an equal number of boys and girls in the total sample of 448 elementary and middle school pupils which comprised the following; 29 grade 4 pupils; 151 grade 5 pupils; 178 grade 6 pupils; and 90 grade 7 pupils. Data from this sample were analysed to provide information about the psychometric characteristics of ESLEQ.

RESULTS AND DISCUSSION

Means and Standard Deviations

Means and standard deviations for each of the ESLEQ items are contained in Table 1. The means for each of the three scales were as follows: the role of the teacher, 4.0; pupil involvement, 2.8; and pupil satisfaction, 3.6. The data suggest a number of interesting observations which may have implications for science teaching in elementary and middle school classrooms. Firstly, although students generally appeared to perceive their teachers as fulfilling the roles as defined by ESLEQ, there is some

concern that they may not be giving sufficient consideration to the individual needs and feelings of all students in the class (see items 4, 13, 25 and 31). Secondly, the data strongly suggest that the opportunities for pupil involvement are somewhat restrictive. In particular, there appear to be limited opportunities for students to provide, select and handle equipment (see items 2, 5 and 32) and even less opportunity for them to select the work to be done in science lessons (see items 11, 14 and 17). The possible lack of opportunities for students to take measurements during science lessons (see item 8) also raises an important issue in science teaching as the processing of quantitative data provides the key to mastery of a number of important process skill objectives. Finally, it is interesting to note that, while students are generally quite satisfied with the science programmes implemented in their classrooms, they do not perceive a strong need for an increase in the number of science lessons (see items 3 and 18).

Insert Table 1 About Here

Internal Consistency

An internal consistency estimate of reliability for each of the three scales was calculated using coefficient alpha (Cronbach, 1951). The coefficient alpha measure for each scale was: Role of the Teacher, 0.78; Pupil Involvement, 0.71; and Pupil Satisfaction, 0.85. These measures of internal consistency are sufficiently high to suggest that ESLEQ may be used to differentiate scale performance between individuals as well as between classes.

Discriminant Validity

The correlation matrix presented in Table 2 contains coefficients that indicate interrelationships for the three scales. Results suggest that ESLEQ measures three separate but also interrelated aspects of the learning environment in science classrooms. These correlations are statistically significant beyond the .01 level and were not completely unanticipated. Two logical reasons for this can be provided. Firstly, there is a need for considerable cooperation and task sharing between both teacher and pupil in fulfilling their respective roles during science lessons; and, secondly, it is probable that pupil satisfaction is to some extent dependent upon both the role played by the teacher and the opportunities provided by the teacher for pupil involvement. Although Table 2 suggests that each of the scales are substantially interrelated, they may be treated independently in analyses provided that conservative interpretations are employed.

Insert Table 2 About Here

Factor Analysis of ESLEQ Data

Factor analysis was used to obtain information related to the structure of ESLEQ. Results from the principal factor solution indicated that ninety one percent of the common variance was accounted for by three factors. Joint application of the scree test (Cattell, 1966) and the Kaiser criterion (Kaiser, 1960) also supported a three factor solution. A promax rotation was used to obtain a final solution in which the factors were allowed to be correlated. The criterion of 0.3, recommended by Child (1970), was applied to decide which factor loadings were to be regarded as being statistically significant. The significant factor structure coefficients ranged from 0.37 to 0.79. These values indicate that each of the items has a high correlation with the underlying dimension of the scale to which it was assigned. The significant factor pattern coefficients ranged from 0.30 to 0.81 and suggest that ESLEQ can be used to provide measures of three distinct but interrelated aspects of the science learning environment; the role of the teacher, pupil involvement, and pupil satisfaction. The factor pattern and factor structure coefficients are contained in Tables 3 and 4.

Insert Tables 3 and 4 About Here

SUMMARY AND APPLICATIONS

The Elementary Science Learning Environment Questionnaire (ESLEQ) was developed to measure three dimensions of the psychosocial learning environment in elementary science classrooms; The Role of the Teacher, Pupil Involvement, and Pupil Satisfaction. Psychometric data indicate that each of the three scales has an internal consistency which is sufficiently reliable to be used in studies, involving pupils from grades 4 to 7, in which classes or individuals provide a focus. Administration of ESLEQ requires, at most, about half an hour of class time and results may be hand scored as indicated in a prior section of this paper. ESLEQ may be used to support research or, alternatively, it may be used for evaluative purposes.

Classroom teachers may find ESLEQ a useful instrument to include as an integral part of their on-going science program as it may

be used to provide baseline and evaluative data on a whole class, small group or individual basis.Administration of the preferred version to a newly allocated class or, to a previously established class, can provide the teacher with valuable information as to how pupils would like the science program to be implemented or changed. Not only can the information gained be of use in planning classroom initiatives but it may also provide valuable implications for attending to individual pupils. As an evaluative tool, the actual version of ESLEQ may be administered at the completion of a particular topic or unit of work, at the end of a school term or towards the close of a school year. Student perceptions of their own involvement, their satisfaction with science and of the role played by their teacher can provide valuable feedback for the teacher with implications for areas such as classroom management, teacher pupil interactions and teaching strategies.

Curriculum evaluators and school administrators, responsible for evaluating and/or modifying science programs at elementary or middle school level, could use both versions of ESLEQ to monitor science classrooms on a single class basis, a whole school basis or across a number of schools. Data obtained from the actual version of ESLEQ would provide a record on the teaching of science in a given class or school, or across a number of schools. Interpretations of the results derived from the analysis of data for each scale would provide an indication of the teaching strategies adopted by teachers, the degree of pupil involvement and the amount of pupil satisfaction. Parallel data obtained from administering the preferred version of ESLEQ would provide an indication of the changes that could be implemented in order to modify existing programmes so as to more fully meet the needs of pupils as indicated by their preferences.

In teacher education institutions, ESLEQ could provide valuable feedback for pre-service or in-service teachers and supervisors involved in micro-teaching or field experience programs. Use of the pupil preferred version of ESLEQ prior to the commencement of micro-teaching or field practice programs can provide intending participants with advanced information on the roles to be adopted by teachers, the degree of involvement desired by pupils and the types of science lessons in which they would prefer to become involved. Administration of the pupil actual version of ESLEQ to pupils involved in such programs would compliment existing evaluation packages by providing an indication of pupil perceptions of the science taught.

ESLEQ can, with some slight modification, be used to obtain data of teacher perceptions as well as pupil perceptions of the psychosocial learning environment in elementary and middle school science classrooms. Such applications involve the use of both versions of the form to measure teacher as well as pupil actual and preferred perceptions of the learning environment. The resulting profiles of environment scores provide a comprehensive basis for reflection upon initiatives most likely to eventuate in subsequent improvement of existing science classroom environments

in order to more fully satisfy the preferences of both teachers and pupils. With one exception, (see Fraser, 1981), very little research of this type has been carried out in science classrooms.

Science has much to offer in the education of pupils at the elementary and middle school levels. The Search for Excellence in Science Education (see Johnson, 1983) draws attention to a number of critical features involved in effective science teaching. Basically, the implications are that teachers have vital roles to fulfil while pupils must be actively involved in materials-centred science activities from which they derive appropriate satisfaction. As ESLEQ provides measures of teacher performance, pupil involvement and pupil satisfaction in elementary and middle school science classrooms the resulting data can be used to plan strategies aimed at promoting the effectiveness of science teaching at those levels.

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FIGURE 1

DESCRIPTIVE INFORMATION ON ITEMS INITIALLY SELECTED FOR INCLUSION IN ESLEQ

ITEM	INSTRUMENT	SCALE	MOO'S GENERAL CATEGORY
The teacher talks with each student.	ICEQ	Personal-ization	Relationship Dimensions
The teacher takes a personal interast in each student.	ICEQ	Personal-ization	Relationship Dimensions
The teacher is unfriendly to students.	ICEQ	Personal-ization	Relationship Dimensions
The teacher helps each student who is having trouble with the work.	ICEQ	Personal-ization	Relationship Dimensions
The teacher considers student's feelings.	ICEQ	Personal-ization	Relationship Dimensions
Students give their opinions during discussions.	ICEQ	Particip-ation	Relationship Dimensions
The teacher lectures without students asking or answering questions.	ICEQ	Particip-ation	Relationship Dimensions
Students ideas and suggestions are used during classroom discussion.	ICEQ	Particip-ation	Relationship Dimensions
Students ask the teacher questions.	ICEQ	Particip-ation	Relationship Dimensions
There is classroom discussion.	ICEQ	Particip-ation	Relationship Dimensions
The pupils enjoy their schoolwork in my class.	MCI	Satisfac-tion	Relationship Dimensions
Some pupils are not happy in class.	MCI	Satisfac-tion	Relationship Dimensions
Children seem to like the class.	MCI	Satisfac-tion	Relationship Dimensions
Some of the pupils don't like the class.	MCI	Satisfac-tion	Relationship Dimensions
The class is fun.	MCI	Satisfac-tion	Relationship Dimensions

FIGURE 1 (continued)

DESCRIPTIVE INFORMATION ON ITEMS INITIALLY SELECTED FOR INCLUSION IN ESLEQ

ITEM	INSTRUMENT	SCALE	MOO'S GENERAL CATEGORY
The teacher decides where students sit.	ICEQ	Independence	Personal Development Dimensions
Students choose their partners for group work.	ICEQ	Independence	Personal Development Dimensions
Students are told how to behave in the classroom.	ICEQ	Independence	Personal Development Dimensions
The teacher decides which students should work together.	ICEQ	Independence	Personal Development Dimensions
The teacher decides how much movement and talk there should be in the classroom.	ICEQ	Independence	Personal Development Dimensions
Students find out the answers to questions from textbooks rather than from investigations.	ICEQ	Investigation	Personal Development Dimensions
Students carry out investigations to test ideas.	ICEQ	Investigation	Personal Development Dimensions
Students carry out investigations to answer questions coming from class discussions.	ICEQ	Investigation	Personal Development Dimensions.
Students explain the meanings of statements, diagrams and graphs.	ICEQ	Investigation	Personal Development Dimensions
Students carry out investigations to answer questions which puzzle them.	ICEQ	Investigation	Personal Development Dimensions

FIGURE 1 (continued)

DESCRIPTIVE INFORMATION ON ITEMS INITIALLY SELECTED FOR INCLUSION IN ESLEQ

ITEM	INSTRUMENT	SCALE	MOO'S GENERAL CATEGORY
The books and equipment students need or want are easily available in the classroom.	LEI	Material Environment	System Dimensions
The students would be proud to show their classroom to a visitor.	LEI	Material Environment	System Dimensions
My classroom is bright and comfortable.	LEI	Material Environment	System Dimensions
There are displays around my classroom.	LEI	Material Environment	System Dimensions
My classroom is too crowded.	LEI	Material Environment	System Dimensions
My teacher gets me interested in new lessons.	TPAI (SP)	Classroom Procedures	System Dimensions
My teacher tells me why the things we learn in school are important.	TPAI (SP)	Classroom Procedures	System Dimensions
My teacher tells me when my answers are right and wrong.	TPAI (SP)	Classroom Procedures	System Dimensions
My teacher does things to keep me working or paying attention during the lesson.	TPAI (SP)	Classroom Procedures	System Dimensions
My teacher gives clear explanations and directions about my class work.	TPAI (SP)	Classroom Procedures	System Dimensions

Table 1

Mean and Standard Deviation for Items Contained in ESLEQ

Item	Mean	Standard Deviation	Number of Respondents
Scale : Role of the Teacher			
1	4.1	1.2	433
4	3.2	1.4	361
7	4.2	1.1	432
10	4.0	1.2	419
13	3.9	1.2	428
16	4.6	0.8	437
19	4.0	1.2	420
22	4.3	1.0	425
25	3.9	1.2	422
28	4.0	1.2	436
31	3.6	1.3	411
Scale: Pupil Involvement			
2	2.3	1.3	427
5	2.6	1.3	416
8	2.9	1.3	407
11	1.8	1.2	413
14	2.4	1.2	399
17	2.9	1.3	424
20	3.4	1.2	423
23	3.2	1.3	425
26	3.2	1.2	409
29	3.5	1.5	432
32	2.8	1.4	427
Scale: Pupil Satisfaction			
3	3.1	1.5	384
6	3.3	1.3	420
9	3.4	1.2	413
12	3.5	1.2	415
15	3.7	0.9	418
18	3.1	1.5	355
21	3.6	1.2	414
24	3.6	1.3	403
27	4.3	1.0	412
30	4.4	0.9	427

Table 2

Intercorrelations Among the Three Scales of ESLEQ (n = 438)

Scale	Correlations with other Scales		
	Scale 1	Scale 2	Scale 3
Scale 1 - Role of the Teacher	1.00		
Scale 2 - Pupil Involvement	.39	1.00	
Scale 3 - Pupil Satisfaction	.32	.40	1.00

TABLE 4

Factor Structure Coefficients Obtained from Promax Rotation

Item	Factor		
	Pupil Satisfaction	Role of the Teacher	Pupil Involvement
1	0.29	0.62	0.15
2	0.14	0.14	0.50
3	0.79	0.24	0.19
4	0.12	0.54	0.20
5	0.16	0.19	0.49
6	0.77	0.22	0.22
7	0.17	0.53	0.18
8	0.18	0.20	0.50
9	0.76	0.36	0.18
10	0.18	0.54	0.26
11	0.16	-0.02	0.41
12	0.73	0.23	0.23
13	0.24	0.61	0.34
14	0.11	0.12	0.43
15	0.63	0.17	0.18
16	0.23	0.55	0.19
17	0.11	0.24	0.45
18	0.63	0.16	0.24
19	0.14	0.46	0.18
20	0.30	0.24	0.37
21	0.65	0.38	0.24
22	0.32	0.51	0.10
23	0.15	0.30	0.44
24	0.64	0.48	0.25
25	0.26	0.51	0.28
26	0.18	0.33	0.42
27	0.37	0.29	0.12
28	0.33	0.46	0.20
29	0.08	0.28	0.40
30	0.37	0.27	0.22
31	0.15	0.41	0.34
32	0.23	0.26	0.45

TABLE 3

Factor Pattern Coefficients Obtained from Promax Rotation

Item	Factor		
	Pupil Satisfaction	Role of the Teacher	Pupil Involvement
1	0.09	0.63	-0.10
2	0.02	-0.05	0.52
3	0.81	-0.04	-0.03
4	-0.09	0.56	0.02
5	0.01	0.01	0.48
6	0.80	-0.08	0.02
7	-0.02	0.54	-0.01
8	0.03	0.02	0.48
9	0.74	0.11	-0.07
10	-0.03	0.53	0.07
11	0.11	-0.23	0.46
12	0.74	-0.06	0.04
13	0.01	0.56	0.14
14	0.01	-0.04	0.45
15	0.66	-0.07	0.02
16	0.04	0.54	-0.02
17	-0.05	0.11	0.43
18	0.65	-0.11	0.09
19	-0.04	0.46	0.02
20	0.19	0.06	0.30
21	0.59	0.16	0.01
22	0.17	0.50	-0.13
23	-0.02	0.17	0.39
24	0.54	0.28	-0.01
25	0.07	0.44	0.09
26	-0.08	0.18	0.36
27	0.31	0.19	-0.04
28	0.18	0.40	0.01
29	-0.08	0.18	0.36
30	0.30	0.13	0.08
31	-0.04	0.35	0.23
32	0.09	0.08	0.40

PREFERRED SCIENCE LEARNING ENVIRONMENT

NAME: ..... YEAR: .....

HOW WOULD YOU PREFER SCIENCE IN YOUR CLASSROOM TO BE ?	VERY OFTEN	FAIRLY OFTEN	SOME TIMES	NOT VERY OFTEN	HARDLY EVER	I DON'T KNOW
1. Our teacher would teach science in a friendly way.	*	*	*	*	*	*
2. Pupils in our class would choose the equipment that they would like to use during science lessons.	*	*	*	*	*	*
3. Pupils in our class would enjoy having more science lessons.	*	*	*	*	*	*
4. Our teacher would consider what each pupil thinks about science.	*	*	*	*	*	*
5. Pupils in our class would set up the equipment for doing science experiments.	*	*	*	*	*	*
6. Pupils in our class would look forward to having science lessons.	*	*	*	*	*	*
7. Our teacher would answer pupils' questions about our work in science.	*	*	*	*	*	*
8. Pupils in our class would take measurements during science lessons.	*	*	*	*	*	*
9. Pupils in our class would be happy during science lessons.	*	*	*	*	*	*
10. Our teacher would explain why pupils' answers in science lessons are right and wrong.	*	*	*	*	*	*
11. Pupils in our class would select the work to be done in science lessons.	*	*	*	*	*	*
12. Pupils in our class would think that science lessons are good fun.	*	*	*	*	*	*

FIGURE 2

IN YOUR CLASSROOM TO BE ?	OFTEN	OFTEN	TIMES	OFTEN	EVER	KNOW
13. Our teacher would explain why the things to be learnt in science are important.	*	*	*	*	*	*
14. Pupils in our class would carry out science experiments suggested by other members of the class.	*	*	*	*	*	*
15. Pupils in our class would enjoy science lessons.	*	*	*	*	*	*
16. Our teacher would clearly explain the work to be done in science lessons.	*	*	*	*	*	*
17. Pupils would provide ideas to be used in science lessons.	*	*	*	*	*	*
18. Pupils in our class would like to do more science when they go to high school.	*	*	*	*	*	*
19. Our teacher would help pupils who find the work in science difficult.	*	*	*	*	*	*
20. Pupils in our class would help one another during science lessons.	*	*	*	*	*	*
21. Pupils in our class would think that science lessons are interesting.	*	*	*	*	*	*
22. Our teacher would encourage pupils to do well in science lessons.	*	*	*	*	*	*
23. Pupils would explain to the class what they have found out from science experiments.	*	*	*	*	*	*
24. Pupils in our class would like the way that science is taught.	*	*	*	*	*	*
25. Our teacher would take a personal interest in the science work that each pupil does.	*	*	*	*	*	*
26. Pupils in our class would carry out science experiments to answer questions which puzzle them.	*	*	*	*	*	*
27. Pupils in our class would like to use science equipment.	*	*	*	*	*	*
28. Our teacher would provide enough equipment for the class to use in science lessons.	*	*	*	*	*	*

HOW WOULD YOU PREFER SCIENCE IN YOUR CLASSROOM TO BE ?	VERY OFTEN	FAIRLY OFTEN	SOME-TIMES	NOT VERY OFTEN	HARDLY EVER	I DON'T KNOW
29. Pupils in our class would help tidy up after science lessons.	*	*	*	*	*	*
30. Pupils in our class would like being able to do experiments during science lessons.	*	*	*	*	*	*
31. Pupils would be encouraged to give their opinions during science lessons.	*	*	*	*	*	*
32. Pupils in our class would bring equipment from home to be used in science lessons.	*	*	*	*	*	*

SCIENCE LEARNING ENVIRONMENT

NAME: ..... YEAR: .....

WHAT IS SCIENCE IN YOUR CLASSROOM ACTUALLY LIKE ?	VERY OFTEN	FAIRLY OFTEN	SOME-TIMES	NOT VERY OFTEN	HARDLY EVER	I DON'T KNOW
1. Our teacher teaches science in a friendly way.	*	*	*	*	*	*
2. Pupils in our class choose the equipment that they would like to use during science lessons.	*	*	*	*	*	*
3. Pupils in our class would enjoy having even more science lessons.	*	*	*	*	*	*
4. Our teacher considers what each pupil thinks about science.	*	*	*	*	*	*
5. Pupils in our class set up the equipment for doing science experiments.	*	*	*	*	*	*
6. Pupils in our class look forward to having science lessons.	*	*	*	*	*	*
7. Our teacher answers pupils' questions about our work in science.	*	*	*	*	*	*
8. Pupils in our class take measurements during science lessons.	*	*	*	*	*	*
9. Pupils in our class are happy during science lessons.	*	*	*	*	*	*
10. Our teacher explains why pupils' answers in science lessons are right and wrong.	*	*	*	*	*	*
11. Pupils in our class select the work to be done in science lessons.	*	*	*	*	*	*
12. Pupils in our class think that science lessons are good fun.	*	*	*	*	*	*

FIGURE 3

WHAT IS SCIENCE IN YOUR CLASSROOM ACTUALLY LIKE ?	VERY OFTEN	FAIRLY OFTEN	SOME-TIMES	NOT VERY OFTEN	HARDLY EVER	I DON'T KNOW
13. Our teacher explains why the things to be learnt in science lessons are important.	*	*	*	*	*	*
14. Pupils in our class carry out science experiments suggested by other members of the class.	*	*	*	*	*	*
15. Pupils in our class enjoy science lessons	*	*	*	*	*	*
16. Our teacher clearly explains the work to be done in science lessons.	*	*	*	*	*	*
17. Pupils provide ideas to be used in science lessons.	*	*	*	*	*	*
18. Pupils in our class would like to do more science when they go to high school.	*	*	*	*	*	*
19. Our teacher helps pupils who find the work in science difficult.	*	*	*	*	*	*
20. Pupils in our class help one another during science lessons.	*	*	*	*	*	*
21. Pupils in our class think that science lessons are interesting.	*	*	*	*	*	*
22. Our teacher encourages pupils to do well in science lessons.	*	*	*	*	*	*
23. Pupils explain to the class what they have found out from science experiments.	*	*	*	*	*	*
24. Pupils in our class like the way that science is taught.	*	*	*	*	*	*
25. Our teacher takes a personal interest in the science work that each pupil does.	*	*	*	*	*	*
26. Pupils in our class carry out science experiments to answer questions which puzzle them.	*	*	*	*	*	*
27. Pupils in our class like to use science equipment.	*	*	*	*	*	*
28. Our teacher provides enough equipment for the class to use in science lessons.	*	*	*	*	*	*

WHAT IS SCIENCE IN YOUR CLASSROOM ACTUALLY LIKE ?	VERY OFTEN	FAIRLY OFTEN	SOME-TIMES	NOT VERY OFTEN	HARDLY EVER	I DON'T KNOW
29. Pupils in our class help tidy up after science lessons.	*	*	*	*	*	*
30. Pupils in our class like being able to do experiments during science lessons.	*	*	*	*	*	*
31. Pupils are encouraged to give their opinions during science lessons.	*	*	*	*	*	*
32. Pupils in our class bring equipment from home to be used in science lessons.	*	*	*	*	*	*

THE EFFECT OF IN-SERVICE TRAINING ON TEACHER ATTITUDES AND PRIMARY SCHOOLS SCIENCE CLASSROOM CLIMATES.

PAULINE HUTCHINSON, EDUCATION DEPARTMENT OF WESTERN AUSTRALIA.

This research stems from a concern for the under participation of girls in physical science. The effect of teacher's implicit assumptions and expectations about students is a well recognised factor in the outcomes of education. The hypothesis developed in this research was that by changing teachers' attitudes towards girls in the physical sciences we could change classroom climate so that girls could benefit more from schooling in this area.

The Report 'Girls School and Society' quotes Rowell (1971) who found a significant relationship between teachers' attitudes and science achievement by girls.

The under achievement and under participation of girls in upper secondary levels of schooling is well documented. In Western Australia, Brown and Fitzpatrick (1981) measured 2.75 males to every 1 female taking physical sciences at upper secondary level. This result is *despite* the fact that in this stage Year 10 girls and boys have relatively consistent performance. If ability is not the criterion for continued participation then attitude must play an important role. Comber and Keeves (1973) in their report of the TEA Project, found the under achievement of girls in Mathematics and Science to be a factor common across most of the 19 countries they surveyed. Participation of girls in science was variable and ranged from 2% in one school in the United Kingdom to 66% in another. It seems as though participation rates are affected by variables such as classroom climate and teacher attitude.

There are several reasons for concern about this phenomenon. Society needs scientists and technologists and many possible future workers in these areas are not being skilled. By conforming to a feminine stereotype which excludes science, girls are cut off from a wide range of interests and occupations at an early age, often before career choice is made. People need sufficient scientific knowledge to take part in the society that science is changing, and to understand the issues involved in that change. A scientific knowledge is also required for a feeling of confidence and environmental mastery in an increasingly technological world.

Sex differences in science achievement are explained by three main hypotheses (Kelly 1981). First, girls are socialised away from physical science at an early age by the toys and games they are encouraged to play with, household jobs they are asked to help with and the masculine image of science. Second, science is presented in schools in a way more suited to girls than to boys. Third, girls perform less well than boys in science because girls have a less favourable attitude towards science. When Kelly applied these hypotheses to Comber and Keeves' findings, the third hypothesis, that of attitude towards science, was held to be a valid reason, across countries, for girls' low achievement in science.

This research however was more concerned with under participation in science. (Kelly 1982) gives three reasons for girls dropping physical science:

- o a lack of self confidence and fear that science is too difficult.
- o the masculine image of the physical sciences
- o an apparent remoteness of science from girls' everyday concerns.

A Lack of self confidence and fear that science is too difficult.

Evidence suggests that science is not too hard, therefore to encourage girls to participate in the physical sciences, it is necessary to concentrate on improving self concept.

The negative attitude towards the physical sciences is often quoted, see, for example Summons (1980).

To improve the classroom climate for girls in physical science lessons, Galton (1981) suggested that a child centred practical learning style should be adapted where chances of direct intervention by the teacher are minimised. Girls appreciate an 'end product' focus to a lesson, while Summons (1980) suggested that both boys and girls like practical independent activity but that girls must be positively encouraged to use physical science apparatus because of their lack of previous background experience.

It has been found by several studies and reported by Spender (1982) that both sexes regard talking in class, questioning and challenging, as typical male behaviour. Boys demand and receive far more time and attention in class than girls. If teachers give more than 35% of their time to girls they feel that they are being unfair to the boys. There is evidence to suggest that there is sex bias in the verbal evaluation of academic work and estimates of children's ability and in patterns of praise and criticism. Teachers must be aware of these findings if improved classroom climate for the maintenance of girls' self-esteem is to evolve.

The masculine image of science

Kelly says (1981:73), 'The characteristically low achievement of girls in science is an aspect of feminine sex role - that is, learned behaviour which is appropriate for females in our society.'

This feminine sex role classifies girls as submissive, well behaved, neat, clean, sweet, gentle and incompetent. Boys, on the other hand, tend to be classified as strong, adventurous, dominant, independent and competent.

'If science achievement has a masculine image in any society, then boys will be motivated to achieve competence in science as part of their developing masculinity; conversely girls will see success in science as incompatible with their developing femininity and so avoid it.' (Kelly 1980:79).

Teachers must be aware of the adverse long term effects of such stereotyping and the part that they play in perpetuating it.

The apparent remoteness of science from girls' every day concerns.

Kahle and Lakes (1983) produce data to show that by age nine girls express interest but do not engage in as many science activities as boys.

Stereotyped assumptions are held about girls' futures. It is still widely believed by teachers that girls will primarily be wives and mothers and treat them accordingly (Scott 1980), despite the fact that sex roles are changing and there is a proven trend towards a more egalitarian conception of women's roles which includes the right to be part of the paid workforce (Thornton et. al. 1982).

Girls need to be shown that physical science is relevant to them. They need to develop scientific skills and become interested in physical science concepts to function with a minimum of environmental mastery in our technological society.

The process of deterring girls from choosing physical science as a subject that they wish to continue studying begins when we encourage them to relate to the personal and subjective while boys begin to grapple with the impersonal and objective (Scott 1980).

As Whyte says (1981:276). "If science teachers are simply aware that, because of its masculine image, girls need all sorts of positive encouragement to enjoy science, they begin to prevent female pupils dropping out.'

In this research we set out to in-service 10 teachers in the effects of stereotyping, women's workforce experience, subject choice and classroom interaction and behaviour patterns. The in-service sessions also included experience in a physical science topic (electricity) and helped in programming to increase teacher confidence with a physical science topic.

To select the teachers to take part in the in-service a questionnaire was administered to all Year 5 teachers of science in the North West Metropolitan Region of Western Australia. This examined teacher background, qualifications, preferred science teaching area and teacher's attitude to male and female students participation in science lessons. Five male and five female teachers were selected to take part in a two day in-service course as an agent for attitude change.

A further ten teachers were cross matched as a control group, and were in-serviced for half a day on the 'hands on' and programme planning section of the course to remove the variable of extra science in-service from the design.

These teachers will now administer a student attitude/interest questionnaire in their classes. Both the experimental group and the control group will be observed while teaching a series of six planned lessons on the topic of 'electricity'. Results will be compared of any differences between the two groups of teachers and students.

Shrigley says (1983: 204) when speaking of the failure of science to gain a postion of legitimacy in the classroom: 'I believe our success has been dulled by ignoring the force of teacher attitude, which, in general is less than positive, and how this attitude has resulted in teaching behaviour that has not supported science adequately. Therefore I am suggesting a model for improvement of the science attitudes of teachers.'

Shrigleys model includes the three components of 'persuade', 'mandate' and 'reward'.

The component of'persuasion'is based on a learning theory approach that assumes humans to be rational, and that new attitudes are learned cognitively much as we learn to read or write. This component in the primary science in-service is recognised by the use of the primary science adviser and other experts for various inputs; the use of audio visual material, hands on experimental work to increase skills, classroom action research and assistance in programme planning.

The component of 'mandate' is included for those who are still reluctant to change. Persuasion theory states that attitude change preceeds behavioural change, however when a mandate is introduced the behavioural change thus enforced can lead to attitude change. The mandate in this research is for the teachers to deliver the six planned lessons and be observed in their classrooms during one of these lessons.

There is evidence that a 'reward' component to in-service provides a more positive attitude and the change is more easily facilitated. Rewards to teachers in this programme consist of the provision of teacher relief days, provision of physical resources for use in their classroom, recognition and respect for their professional capacity, follow-up communication links to the adviser and the co-ordinator should problems occur or queries arise.

Some Early Findings

Some preliminary findings from the teacher questionnaire showed the following male female differentiation.

	MALE	FEMALE
Prefer not to teach the area * 'Energy'.	14.7%	31%
Prefer not to teach physical science.	9%	23%
Preferred biological topics	28%	62%
Preferred physical topics	34%	15%

Male teachers programmed more physical science topics.
Female teachers programmed more biological science topics.

There were few perceptions of sex difference in children's attitude towards the sciences. Although there was a slight perceived difference in confidence towards physical or biological sciences, this was not statistically significant.

* The topic chosen as a typical physical science topic for that grade level.

  Also this topic is used for the 'hands on' experience, programme planning and lesson observation in the research.

Items that were statistically significant when rating differences between perceived attitudes of boys and girls were:

Girls were seen to take a greater pride in their work.

Male teachers saw girls as getting better results than boys in biological sciences.

It was interesting to note that wherever boys and girls were required to be rated, female teachers rated a higher proportion on every item (i.e. proportion of children responding).

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TEACHER PREFERENCES FOR AREAS OF SCIENCE

	Prefer to teach		Prefer NOT to teach	
	Male	Female	Male	Female
animals, plants	28%	62%	12%	12%
matter, energy	34%	15%	26%	54%
no preference	38%	24%	62%	35%
n	34	26	34	26

TEACHER PERCEPTIONS ABOUT THEIR

OWN SCIENCE TEACHING

		ANIMALS	PLANTS	MATTER	ENERGY	n
TEACHER MOTIVATION	M	2.15	2.12	2.18	2.21	34
	F	2.32	2.44	2.09	1.78	26
BACKGROUND KNOWLEDGE	M	1.97	1.79	1.94 *	1.91 *	34
	F	2.04	2.04	1.52	1.36	26
SKILL IN TEACHING	M	2.32	2.26	2.35	2.18 *	34
	F	2.42	2.46	2.04	1.76	26

POSSIBLE SCORE RANGE 1-3

* $p < .05$

TEACHER PERCEPTIONS OF THE EASINESS OF SCIENCE

MALE

	ANIMALS	PLANTS	MATTER	ENERGY
EASINESS FOR BOYS	2.73	2.55	2.27	2.27
EASINESS FOR GIRLS	2.73	2.58	2.24	2.21

Responses to question

'In my experience, boys (girls) generally find this area

Easy to understand	Scored 3
Presents occasional difficulties	" 2
Hard to understand	" 1

FEMALE

	ANIMALS	PLANTS	MATTER	ENERGY
EASINESS FOR BOYS	2.81	2.69	2.48	2.52 *
EASINESS FOR GIRLS	2.81	2.81	2.24	2.16 *

* $p < .05$

WHY TEACH SCIENCE?

Leonie J. Rennie
University of Western Australia

In Western Australia, the teaching of science is taken for granted. Science is actively encouraged at the primary level, it is a 'core subject' at the lower secondary level, and almost all students take at least one science subject at the upper secondary level. This commitment to science should not make the question addressed by this paper a rhetorical one. Science is, after all, an expensive subject, requiring special rooms, specialised equipment and extra staff just to look after it. Even in the primary school, some extra equipment is needed, which has to be looked after, and stored somewhere. If money is to be saved in education, cutting science would be an effective means of cutting costs.

Suppose cuts to science were proposed: could we, indeed should we, argue against such cuts? Successful argument requires a persuasive answer to the question 'Why teach science?', particularly at the primary level. The inclusion of some science in the secondary school might successfully be justified in a vocational sense, because there are some vocations for which employers or training institutions make science a prerequisite. An argument based on vocational choice is more difficult to sustain at the primary level, several years before students leave school.

So why teach science in the primary school? This paper examines some of the reasons typically found in documents relating to primary science, finds out what priority a group of Year 5 teachers gives to these reasons, and looks at the contribution of science to the total education of children at the primary level.

The Rationale for Primary Science

An analysis by Pearce (1981) of documents on Primary Science Education from Australian State Education Departments found a number of common features. The documents all are guidelines, rather than prescriptions, for an activity-based, child-oriented approach to teaching science. There is general agreement for three broad course objectives: the acquisition by the child of positive attitudes (towards scientific enquiry, science, and the environment); of the process skills of science; and of certain science concepts and understandings. While the aims and objectives of all State courses are spelled out in some detail, Pearce (1981, p.34) asks why there is relatively little attention given to the rationale for the teaching of science.[1] Three States' documents included some expression of rationale, while for other States, the rationale must be deduced through analysis of the stated aims and objectives.

Pearce (1981, p.28) found four points of consensus among all States for a rationale for the teaching of science. In outline, these are first, that science contributes to the *intellectual development* of the child, giving him the skills required for rational and independent thought and responsible action; second, it is important that the child develops some understanding of

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1. The recently published K-7 Science Syllabus (Education Department of Western Australia, 1983) rectifies this deficiency in the draft edition of the Primary Science Syllabus in this State.

the ways of science in order to cope with technological change, and make use of *science in his everyday life*; third, science enables the child to *observe understand and appreciate his environment*; fourth, doing science overlaps with skills used in other areas, enhancing these aspects of the curriculum and allowing *integration with other subject areas*. A fifth point, noted in three States' Documents, was that science assists in the *social and emotional development* of the child.

If this rationale is accepted as a description of what doing science can contribute to the education of primary school children, then two questions must be asked. First, do teachers accept the rationale as providing valid reasons for their science teaching? If they do not, then clearly the rationale will remain as words in the syllabus, not action in the classroom. Second, is the rationale a good enough reason for teaching science in the *primary* school? After all, since the rationale could be just as useful at the secondary level, why not leave science until then?

Do Teachers Accept the Rationale?

The general statements of rationale from Pearce (1981) were used as a starting point to generate a list of reasons for teaching science. At least one reason was listed for each of the five points noted. The reasons were checked against the statements in the primary science syllabus presently available to teachers in this State.[2] After discussion with three primary teachers not involved in the study, an attempt was made to avoid the phraseology typical of statements of aims, because teachers might automatically endorse familiar phrases. Further, the word 'environment' was avoided because specific environmental issues have recently received extensive and emotive media coverage. The final list of eleven reasons appears in Table 1.

The reasons for teaching science comprised one section of a questionnaire administered as part of a larger study of primary science. The teachers selected to participate in the study were those teaching unmixed Year 5 classes in one educational administrative region of the Perth Metropolitan Area. Of the 64 eligible teachers, 60 responded to the questionnaire, of whom 34 were male and 26 were female.

Teachers were asked to rate each of the eleven 'possible reasons for teaching science' according to 'how much importance does your science teaching and programming give to each of these considerations in teaching science to children at the Year 5 level?'. A five point scale, with '5' labelled 'high importance' and '1' labelled 'low importance', was used as the response format. The means and response frequency distributions appear in Table 1. Although the reasons were placed in random order on the questionnaire, they are ranked in three groups in Table 1, according to their mean rating.

Inspection of Table 1 shows that the mean rating of each aim exceeds the midpoint of three, although except for the top three reasons, there is considerable variability in response. It is interesting to note that every reason was rated more highly by female teachers, although the difference in mean rating reached significance at the .05 level only on the fourth, sixth and eighth reasons. However, the reasons were ranked similarly by both male and female teachers so the combined means are reported in Table 1.

Education Department of Western Australia. *Primary Science Syllabus with Notes* (Draft Edition), 1973.

Table 1

Means and Response Frequency Distributions for the Importance of Reasons for Teaching Science

Rank	Reason	Mean	% Response Frequency				
			Low Importance				High Importance
			1	2	3	4	5
1	to interest children in science	4.52	0	0	10	28	62
2	to give practice in problem-solving skills	4.38	0	2	13	30	55
3	to show how science is related to everyday life	4.15	0	2	21	37	40
4	to develop self-discipline and independence	3.96	2	5	28	25	40
5	to give practice in communication skills - verbal	3.93	2	7	20	39	32
6	to develop social skills (such as cooperation)	3.92	2	5	25	37	31
7	to give practice in communication skills - written	3.73	5	7	29	29	30
8	to integrate science with other school subjects	3.53	2	12	38	28	20
9	to provide scientific knowledge	3.47	3	8	42	32	15
10	to give practice in manipulative skills	3.45	8	13	25	34	20
11	to prepare students for science later on	3.40	8	10	34	30	18

In general terms, the relative importance placed by teachers on the reasons for teaching science is not surprising. Teachers give greatest emphasis to children's interest, problem-solving skills and the relationship of science to everyday life. The second group of reasons includes the development of self-discipline and independence, and the acquisition of social and communication skills. These reasons are probably those least specific to science, and all must be relevant to other subjects in the curriculum. Even so, they are commonly espoused as aims in documents relating to science, and clearly teachers support them.

The high importance given by teachers to the relationship of science to everyday life (reason 3) coupled with the relative low importance assigned to providing scientific knowledge (reason 9) and preparing students for science later on (reason 11) is in line with Fensham's recent arguments for a change in direction for science education (Fensham, 1980, 1981; Smith, 1983) away from 'head' (knowledge) and 'heart' (socially relevant) science to 'hands' (meaningful practical skills) science. Although such argument is usually addressed to science at the secondary level, it must be more relevant at the primary level, where students' mental capabilities do not easily cope with the abstractions of the 'big ideas' and social issues relating to science.

The general acceptance by teachers of the rationale for teaching science should not obscure two important issues about primary science. First, there is not much of it. The teachers participating in this study allocated between 35 and 120 minutes to science each week, with an average of around 60 minutes. If one assumes a five-hour teaching day, then about four per cent of teaching time is allocated to science. Second, teaching science in the primary school is not always easy. In a free response section of the questionnaire, two teachers indicated that they taught science because it is a required subject. Another teacher wrote

> when time is short, science is the most likely area to be neglected as (i) I do not feel competent in this area (ii) there is very little science equipment in the school.

Many other teachers wrote that children enjoyed 'hands-on' activity-oriented science, but shortage of equipment, and sometimes their own lack of background knowledge were difficult obstacles to overcome. These problems are not unique to these teachers (Riley, 1983) and indicate the position of science in the primary school to be somewhat precarious. Do we really need it?

Why Teach Science in the Primary School?

An answer to this question can be found by looking at the broader goals of education. According to White (1980, p.6) 'schools are set up by society to produce competent members of that society. So we will teach science only if it contributes to the competence of individuals.' White chooses to discuss the cognitive components of competence and defines a competent person as 'one who has mastered topics which society regards as vital' (White, 1980, p.7). Cognitive competence is a function of both knowledge and skills. Intellectual skills have already been listed and were endorsed by the teachers in this survey, and while such skills are not unique to the primary school, they are certainly important at this level. Teachers gave a relatively low rating to the importance of knowledge, but skills cannot be taught without some content. The place and selection of content in primary science have been well argued by Harlen (1978, 1980) and her arguments will not be reiterated here, but in essence, selection of content can be very flexible, and teachers should have a great deal to do with it.

The meaning of affective competence is suggested by the National Science Teachers Association Position Statement (NSTA, 1971), in which this statement appears among the general goals of education:

> Above all, the school must develop in the individual an ability to learn under his own initiative and an abiding interest in doing so. (p.47)

The acquisition of intellectual skills enable an individual to learn, but a willingness to learn and an interest in doing so, are affective traits closely related to the individual's academic self-concept (Bloom, 1976).

The affective aims of science teaching embodied in the documents surveyed by Pearce (1981), talk about attitudes arising from the science content, the process skills, and from a general perception of science. Some documents mention social attitudes - sharing and communicating with others. There is little mention of the development in the child of positive attitudes toward himself, both as a learner and as a worthwhile person, yet such attitudes are important, even crucial, for the child's future well-being (Bloom, 1976).

In keeping with White's criterion that we will teach science only if it contributes to competence, we ask 'can science contribute to the affective competence of individuals?' It would appear that it can. With a commitment to 'hands-on' activity and flexibility in content, science is uniquely positioned to offer students a say in what they will do, and how they will do it. Taking more responsibility for their own learning helps students to develop positive feelings about themselves, and about the process of learning. This point is developed more fully, and specifically for science education, by De Vito, Krockover and Malcolm (1977).

In a rapidly changing world, the knowledge component of what a child learns may be less important than his approach to learning, and here may be found the answer to the question 'why teach science?' Science offers particular opportunities to contribute to intellectual and affective competence. The development of intellectual skills can begin in primary school and continue in later years of schooling, but the same cannot confidently be assumed for the affective aspects of competence. Bloom (1976, p.155) concludes that academic self-concept is relatively clearly defined by the end of primary school. Leaving science until secondary school may leave until too late the contribution science can make to the development in children of a confidence in their ability to learn and a willingness to do so.

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Identifying Characteristics of Primary Science Teaching Styles.

Leonard N. McKenna

Western Australian College of Advanced Education.

Abstract

The research reported was carried out in 1979 when it was necessary to ascertain primary science teaching styles of graduate pre-service primary school teachers as part of a larger study involving final year teacher education students at a Western Australian College of Advanced Education. Three teaching styles were identified which roughly equate to three styles found in a sample of secondary teachers in Great Britain in a study carried out by Egglestone, Galton and Jones in 1975. In the present study the highest quality cognitive classroom interactions were measured in a teacher-directed teaching style whereas, in the secondary study such interactions were a feature of a style where the children carried out experimental investigation with minimal interference from the teacher.

Instrumentation

Power (1977), Hacker (1980), and Eggleston, Galton, and Jones (1975), have reviewed observational instruments for recording interactions during science lessons. Eggleston et al (1975, p. 24-25), observe that there is little previous experience to call on in the choice of an observation system but conclude that not any of the 120 interaction systems in Mirrors of Behaviour were suitable for their purpose. In their review, the authors made a distinction between theory-dependent observation systems derived deductively and those developed by the process of induction. A third category was also defined- one not constrained by theory but by a behavioural prescription. In this latter type observers are told to look for prescribed teacher or pupil behaviour. The "inductive" systems focus rather exclusively on events initiated by the teacher and the logical development of content. According to Eggleston et al systems in this category produce observations that are seriously restricted in their record of the complexities of science interactions because of the of the limited perspectives of teacher initiated episodes and the need to use transcripts of verbal exchanges. On the other hand, systems using the "deductive" approach, rather than searching for patterns inductively, start from established theoretical models. Not any of the models used were applicable to the objectives set for the study proposed by Eggleston and his associates. The systems of the "prescribed" approach were rejected on the grounds that sufficient details essential to a proper trial and evaluation were not available and further, that in many cases there was too much prescription to lesson structures that were not applicable. The reviewers concluded that as no instrument was available that had

been used to measure more than a dozen teachers there was a need to design one capable of observing 100 teachers. Subsequently the Science Teaching Observational Schedule was developed.

Cluster-analysis of the data collected from about 100 British science classrooms using the Observation Schedule led the developers to the construction of a typology of teaching styles whereby three patterns emerged. Power (1977, p. 8), has designated the patterns reported by Eggleston et al (1975) as: teacher as an actor manager, teacher emphasizing fact finding and fact acquiring, and teacher emphasizing pupil centred inquiring. A description of the three groups and their characteristics follows:

> Group 1 - The initiative is held by the teacher, who challenges his pupils with a comprehensive array of questions- observational, problem solving and speculative - in both practical and theoretical contexts. Teachers' statements also reflect these teachers' orientation towards science as a problem solving activity.
>
> Group II- Characterized by a relatively infrequent use of teachers' questions, excepting those demanding recall and application of facts and principles to problem solving (in the rather convergent sense used in this research). However, there is a relatively high incidence of teachers' statements of fact and teachers' directions to sources for fact finding. There is a non practical bias and fewer transactions are inferential or speculative.
>
> Group III- This group has more uniquely distinctive features than either Group I or Group II. No less than five categories are used with greater frequency by Group III. All these categories fall in the d and e major categories. There is, clearly, a much higher level of pupil participation, both consultation and referral to the teacher. Pupil initiated and maintained behaviour is directed to experimental procedure, in inferring, formulating and testing hypotheses as well as to acquiring and confirming facts. The infrequently used categories are all teacher activities particularly a1- questions of fact, a2- questions of a problem solving type, and b2- statements of problems. This group seems to be very "child centred" when compared to Group I. Their work is, however, practical and the intellectual level of their engagement in it is high. Perhaps the description "pupil centred inquiring" might not be inaccurate.
>
> (Eggleston et al, 1975, p. 66)

The Science Teaching Observation Schedule, however does not meet two important criteria set down for the present study in that it is designed for secondary rather than primary science classes and secondly, use of the instrument requires a large number of trained observers. Fortunately Hacker (1982), has modified the procedures to allow primary classes to be measured. The modified instrument is the Science Lesson Analysis System. In the present study it was necessary for further modification of procedures to be carried out to allow a large number of measurements to be made without the need for a large team of observers. This final form of the Science Lesson Analysis System is used in the present study and is described here.

The Science Lesson Analysis System

The essential modification to the original Science Teaching Observation Schedule is that some of the categories have been amended and expanded. This has been justified in the following way:

> "By providing for increased differentiation among the categories available in the Science Teaching Observation Schedule and adding several behaviours appropriate to primary science, the schedule developed for this study should be capable of producing finer distiction between the patterns of intellectual transactions taking place across all grade levels in science classrooms."
>
> (Hacker, 1982, p. 20)

Hacker's Science Lesson Analysis System score sheet shown in appendix A, enables an observer to sample verbal interactions and also nonverbal interactions with science materials and multi-media materials. Nine such interactions are further subdivided into twelve categories of "purposes for the interaction" giving in total 108 cells available for the classification of selected classroom behaviour. Hacker describes general ground rules for scoring the behaviours as well as more specific rules to decide the type and purpose for the interaction.

When the observer considers that a particular behaviour has occurred a check is placed in the appropriate cell. The lesson is divided into three minute intervals and a score sheet is provided for each three minute period. A cell is checked only once in a three minute period even if the behaviour occurs more than once. No further reference is made to the cell until the next time unit begins.

Each type of behaviour can then be expressed as a percentage of the total number of three minute units. Consider the example of a 30 minute lesson when a certain behaviour has been checked in the appropriate cell on each of four score sheets. In this example there were ten score sheets that is, ten three-minute units of time. The behaviour is recorded as having been observed in 40

percent of the three-minute time units that is, four units out of ten. The Eggleston et al instrument does not provide for the recording of the non-verbal activities which Hacker claims are essential to Piaget's concrete operational period. Hacker's instrument includes a "non-verbal interaction with resource materials" section which makes it possible to distinguish between lessons where the children have been working with science apparatus and those where the children have had the benefit of diagrams and pictures from the blackboard, texts or video displays. The Eggleston et al instrument has a category 2d, labelled as "pupil talk and activity", but there is no way that the two behaviours can be distinguished on the schedule. Further discrimination in terms of Bloom's hierarchical ordering of the cognitive skills that children practice is possible on the Hacker instrument. The Science Teaching Observation Schedule "teacher's talk" categories of- recalling facts and principles (1a1), and applying facts and principles (1a2), contain intellectual skills from separate cognitive divisions of the Bloom taxonomy. Distinct categories for facts and principles in Hacker's instrument provide for more distinction in any attempt to compare Gagne's theory with actual classroom practice. The separation of the lower and higher order skills required in problem solving in category 1a2 also make it possible in the Hacker instrument to examine data for evidence of Guilford's convergent and divergent dimentions of thinking. A further modification made by Hacker, in order to make the Science Lesson Analysis System more relevant to the primary classroom, has been the inclusion of categories dealing with the identification of equipment and procedures.

Modification of Procedures

A serious objection to using either of the two instruments described was the need to use trained observers in the classroom. For a number of reasons this was impracticable and indeed undesirable. For a start the need to observe each student teacher for a 30 minute lesson was beyond the practical limitations of the research, especially since the students were located in schools scattered throughout the Perth metropolitan area and country regions. Further, each student was undergoing a final teaching practice period at the end of which a teaching grade would be awarded. All students were acutely aware of the fact that such a grade would greatly effect their chance of obtaining a teaching appointment in the following year. The presence of an observer during a lesson would almost certainly be confused with assessment of teaching ability and elicit teaching behaviours not conducive to the objectives of the research. What was required was an observation of a teacher's normal science teaching style rather than one in which there was a perceived need to impress a supervisor with attributes such as class control, ability to use teaching aids, good diction and like categories found in the college's "Student Teacher Practice Assessement Sheet". Consequently an alternative to a classroom observer had to be found.

Recording by videotape was unrealistic given the factors involved but audiotape was a possibility providing two obvious difficulties could be overcome: how to hear verbal interactions taking place some distance from the recorder; and how to ascertain what non-verbal interactions were in progress.

The first problem was overcome by requiring each student teacher to conduct a science lesson with a reduced number of children. Eight was decided upon. This meant that each child could be placed within range of the recorder. Student teachers often have a problem of class control which could well effect the conduct of the lesson. A small group would reduce the chance of this variable effecting the outcome. It ensured that the class size was common and by stipulating four boys and four girls to constitute the group, variation due to sex differences could be controlled. The students had had experience in using tape recorders in that they had been required to record and analyse similar small group lessons in the previous year of their course. As an added precaution operating instructions for audio tape recorders were included in a letter to be sent to all students.

The second difficulty, that of determining what non-verbal interactions had taken place, was overcome by requiring each student teacher to prepare a lesson plan setting out the steps of the lesson together with a description of the material to be used. This was to be returned with the tape of the lesson. To test the feasibility of this procedure a number of lessons to small groups were recorded. When the tapes were replayed in association with the written lesson plans no difficulty was experienced in understanding precisely what interactions were taking place. This was later verified by the two lesson raters who were experienced in using the Science Lesson Analysis System in the normal class room situation.

Instructions sent to students

The letter of instructions to students was designed to encourage students to undertake a lesson which would be a "normal" science lesson, similar to one they might conduct after receiving a teaching appointment. Had it been sent by the Science Department the students might have been inclined to conduct a lesson of a style they felt was required of them rather than a style which was their own. Consequently the letter was signed by the Head of the Department of Practical Teaching.

The lesson was to be of 30 minutes duration and was to be a "complete" lesson. A revision or solely introductory lesson would by its very nature not give the opportunity for the full range of interaction categories to be used. The students were instructed to choose their own topic and use a teaching style which was appropriate, but one which was "comfortable" to them. The lesson could be undertaken anywhere in the school but the students were instructed to use the kind of resources that they would have used in normal circumstances (ie blackboard, aids, tables, apparatus

etc). They were also asked to carry out the lesson as if it were to a normal class. All eight children (four boys and four girls) were to be from the same year and were to be chosen from a class which the student teacher had previously taught. A lesson plan sheet was appended to the letter. The headings and general requirements of this were familiar to the students who had been required to draw up similar plans in previous teaching practice sessions.

Data Collection and Sample Description

During the second term for primary schools each student teacher in the final year of the course is assigned a school in which to carry out a final 13 week practice teaching assignment known as the Assistant Teacher Program. In 1979 the program was conducted from May 28th to August 25th. As far as possible the teaching experience is made to resemble the day to day routine of a classroom teacher. It was this practice situation that was selected to collect the data for the measurement of science teaching style.

College tutors are allocated a group of students to visit regularly for advice and assessement. In the first week of July the tutors were asked to deliver a letter and a blank tape to each student teacher and to advise them further on the recording of the taped lesson. The tutors performed an important function in ensuring that the student recorded the lesson and returned the tape and completed lesson plan to the college. Prestamped envelopes were provided to students located in country areas for this purpose. Of the 181 students requested 160 responded with a taped lesson. The students who did not respond tended to come from one group where the tutor was less insistant on students completing the requirements. Since the students were randomly assigned in the first instance and the low number of nonresponders were due mainly to one tutor the data returned was considered still representative of the initial sample.

Validity

Eggleston et al (1976) made claims for the content validity of their instrument on the basis of interviews and questionaires administered to teachers and science educators who were required to assess the importance of specified science teaching objectives and science teaching styles. In addition results reported by the authors indicated that the observation categories significantly correlated with pupil attitude to science. These results attest to criterion related validity of the Science Teaching Observation System . (Eggleston et al, 1976, p. 108). The validity of the Science Lesson Analysis System was assumed since it was a modified version of the former instrument and the changes were comparatively minor.

Reliability

Because some of the 108 cells were not used by some student teachers the reliability of data based on cell frequencies would be low (McGaw, Wardrop and Bunder, 1972). It was decided therefore to create new variables by summing row and column totals. Totalling the cells in each column yielded nine "types of interactions" variables and totalling the cells in each row produced twelve "purposes for interaction" variables.

Interobserver Agreement

Interobserver agreement for the two observers used in the research was calculated using a method described by Eggleston (1975). The categories used were the twelve row totals and nine column totals. Coefficients of agreement obtained are shown in table 1. According to Eggleston et al, (1975, p. 15) "It is usual to regard values of the order of 0.6 as satisfactory". Since the coefficients obtained were considerably higher than 0.6 the agreement was acceptable. Therefore each of the two raters could be expected to observe and code science teaching style in a similar manner. On the basis of the magnitude of the interrater index a decision was made for each audio tape to be rated by a single rater. Audio taped lessons were randomly assigned to each of the two raters.

Internal Consistency Reliability

Eggleston et al (1975) calculated reliability using a modified analysis of variance design used by Medley and Mitzel. The method regards "Both the teachers and the observers as 'fixed' facets ie they are not regarded as a random sample from a larger population." (Eggleston et al 1975, p. 16). Such a decision to regard the raters as a fixed facet overestimates the magnitude of the reliability coefficient obtained for each variable and furthermore the calculation restricts the generalizability of the findings to the specific raters used in the study. As a consequence "raters" in the present study was defined as a random facet for the purpose of calculating generalizability coefficients. The magnitude of these coefficients calculated for each variable provides a measure of the dependability of the data for differentiating subjects and generalizing over time intervals and raters.

The formula used to calculate the generalizability coefficient was that used by Tobin and Capie (1980, p. 6) and is provided below.

$$\rho_s^2 = \frac{\sigma_s^2}{\hat{\sigma}^2 + \frac{1}{n}\left(\hat{\sigma}^2_{\text{residual}}\right)}$$

Where

ρ_s^2 is the generalizability coefficient for differentiating subjects,

$\hat{\sigma}_s^2$ is variance component estimate for subjects,

n is the number of time intervals in which subject behaviour was sampled and

$\hat{\sigma}^2_{residual}$ is a pooled variance component estimate for all other variance sources including error.

The variance component estimates were based on complete data from a random sample of 50 subjects who participated in the study. This sample size was selected on the basis of two constraints. First, in order to assure stable variance component estimates with a design of less than ten levels of each facet, a large sample size is necessary. The reason for this is fully discussed by Tobin and Capie (1981). Secondly the algorithm used to estimate variance components requires a balanced design (Brennan and Deaton, 1980). This second requirement restricted the sample to those subjects whose percentage usage of the categories were based on a completed 30 minute lesson. Some of the lessons had been of shorter duration.

The generalizability coefficients obtained are shown in table 2. According to Cardinet, Tourneur and Allal (1976), if the magnitude of a coefficient is less than 0.8 there is a significant risk of type II errors and results should be interpreted with caution. In the present instance 13 of the coefficients were of the magnitude of 0.8 and above, seven were marginal and one, the coefficient for variable R4, could not be calculated due to an extremely low usage of the categories in this row.

It was considered that the generalizability coefficients were overall of reasonable magnitude reflecting acceptable dependability of data that are aggregated across rows and columns. However caution should be used when interpreting results involving variables that have a generalizability coefficient of less than 0.8. In such cases significant results may be masked by measurement error.

Statistical Procedures

The teaching style data were used as a basis for identifying predominant teaching style groups. Variables used were the twelve row and nine column totals. Groups were formed by analysing the data using a computer program developed by Hacker and Lyne (1981). The method used to allocate teachers to groups involved initial cluster analysis followed by a procedure in which teachers were individually compared with those in each of the clusters. If a student teacher's profile on each category more closely resembled the centroid of another group, the teacher was transferred to that group. An iterative procedure was used to assign each individual

to a more appropriate group. The analysis stopped when all individuals achieved their highest correlation with the group in which they were placed or when the differences became so small that altering the groups only produced alternative minor discrepancies among other individuals. The procedure is fully described by Eggleston et al (1976, p. 61).

The number of groups resulting from this analysis was determined by examination of the dendrogram resulting from the analysis, according to the procedures described by Everett (1974) and Eggleston et al (1976). According to Eggleston et al (1976, p. 62) choice of the number of groups selected was "A result of compromise between the need to have clearly differentiated groupings which is favoured by a small distance coefficient, and the need to have a few groupings of reasonable size, which results in the choice of a large coefficient for the cut-off point." Although a four cluster solution was parsimonious a three group solution was preferred because it was more interpretable in terms of teaching styles.

The science lessons conducted by the student teachers ranged across all levels of the Primary School (see table 3). To ensure that the science teaching style was not influenced by school grade level a Chi-squared test of association was conducted to determine if a relationship existed between the two variables.

Results

Of the 160 students whose lessons were recorded 58 did not complete other measures used in the research. Two of the cases did not fit into the three groups developed by the cluster analysis and these were discarded. The remaining 100 cases numbered 37, 32 and 31 in groups I, II, and III.

The relative frequences of use of the 21 interaction categories by the three groups are compared in figure 4. Each group is compared in turn with the other two. The symbols in the table indicate both the sign of the differences and the significance level as determined by the Mann-Whitney U test. The black spots indicate positive differences and the empty ring negative differences. Double symbols indicate 1 percent significance level and single symbols 5 percent level. Thus in the first section of the figure the two black spots in the first cell- that is line Group II, column R1- means that Group I used this category more frequently tha Group II and this difference was significant at the 5 percent significance level. The cell immediately below- that is line Group II, column R1- is blank meaning that there was no significant difference in the frequency of use of category R1 between Group I and Group III. The open ring in , for instance, cell Group III, R10 in the second section of the table means that Group II used category R10 less than Group III and this difference was significant at the 1 percent significance level. An asterisk at the foot of a column in any section indicates that one particular group of the three differs significantly at either

level from both the remaining groups. Such an asterisk marked category means that that category is unique to one group. At the foot of the table those unique features of each group are summarised.

The result of the analysis of the data on school grade level and science teaching style produced a Chi-square the magnitude of which ($2 = 8.7 < 21.0 = {}^{2}_{.95}$, $p > 0.5$), indicates that the two variables are not related to one another.

Discussion

On the basis of the results presented in table 4 three distinctive science teaching style groups are apparent. The differences between the groups are best illustrated by means of the Venn diagram shown in figure 1. The Venn diagram depicts the categories as three overlapping sets (science teaching style groups). The subsets LMK, KOP and PNM contain those characteristics which are unique to those groups and those which are significantly different from one other group. The boxes around the category indicates that the score on that category differs significantly from the scores of the other two groups. The categories not in boxes have a score that is significantly higher or lower than one other group. Categories which occur in areas of two group overlap (KLO,LMN and ONP) are those shared by two groups such that there is no significant difference between the observed frequencies. The differences which characterize these three groups characterize three science teaching styles henceforth called Style I, II and III. The characteristics of the groups are summarized below.

STYLE I

This style is characterized by a high incidence of teacher and pupil interaction with multi-media material and a low incidence of interaction with science materials. There is a non-practical bias with fewer high quality cognitive transactions involving observing, inferring and speculation. Talk is minimual- in particular, conversation between pupils and pupil talk to teacher. The lesson outcomes are directed almost entirely to the acquisition, recall, or confirmation of facts.

STYLE II

In this style there is an emphasis on student activity. Conversation between pupils and pupil to teacher is at a high level, but teacher talk is mainly confined to giving directives. Essentially the activity is experimental with children interacting with science materials. This style has the lowest incidence of acquisition, recall, or confirmation of facts. There is also a low incidence of use of multi-media materials by teacher and by pupils. However, the level of intellectual activity is not high in fact the activity is mainly confined to carrying out experimental procedures.

STYLE III

This style, because of the frequency of high cognitive interactions, is undoubtably the highest quality teaching style. Four important cognitive interaction categories are used with greater significant frequency than the other two teaching styles, they are: making or testing hypotheses or speculation; making or describing observations; interpreting observed or recorded data; and inferring from observed and recorded data. There are low scores for use of multi-media materials and high scores for use of science materials especially by the teacher. This then, is an essentially practical style but the initiative is held by the teacher who talks (significantly more than in the other two styles) at a high level challenging pupils with an array of questions that are factual, observational, and problem solving. Intellectual level is high with many transactions inferential and speculative.

The three science teaching style groups are readily interpretable in terms of science teaching. Style I could be described as a "teacher-centred" style where the emphasis is on learning facts. Style II is "pupil-centred", while Style III is more "teacher-directed" and speculative.

The three styles identified equate roughly to the secondary teaching styles described by Eggleston et al (1976). But whereas Eggleston's Style III- teachers emphasizing pupil-centred inquiring- was accompanied by a high level of intellectual engagement, the equivalent style in the present study produced a comparitively low intellectual activity that was confined for the most part to experimental procedures. The highest level of intellectual activity in the present study was demonstrated in the "teacher-directed" style. The student teachers in this group also engaged in more "teacher talk" than those in the other two science teaching style groups.

The difference in the two sets of research data undoubtedly reflects the difference in the age of the children used in the two studies. The higher cognitive level of the secondary school students would equip them to reach the higher levels of speculation when an experimental situation affords them the

opportunity. The same does not apply to younger children of lower cognitive levels. When these children are given an experimental type of lesson and are left to their own resources the lesson outcome results in little more than the carrying out of the experimental procedure purely for its own sake. That children reached a high intellectual engagement in the present study with Science Teaching Style III emphasises the importance of the teacher in initiating and guiding the challenging verbal interactions. Such teacher behaviour could well be an important factor in assisting the cognitive development of the child to the level of self sufficiency exhibited by secondary school children observed by Eggleston et al (1976) in his style III- teacher emphasizing pupil centred inquiring.

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Table 1

Coefficients of interobserver agreement for the variables obtained by totalling each column (types of interaction), and each row (purposes for the interaction) of the Science lesson Analysis System

Types of interaction Columns	Coefficients of agreement	
	observer A	observer B
C1	1.00	1.00
C2	0.77	0.80
C3	0.83	0.77
C4	0.88	0.83
C5	0.88	0.83
C6	0.72	0.72
C7	1.00	1.00
C8	1.00	0.94
C9	1.00	1.00
Purposes of interaction Rows		
R1	0.77	0.94
R2	0.88	1.00
R3	0.42	1.00
R4	0.71	0.60
R5	0.88	1.00
R6	0.71	0.77
R7	0.83	1.00
R8	0.81	0.83
R9	0.77	0.54
R10	0.88	0.94
R11	1.00	0.94
R12	0.71	0.83

Table 2

Generalizability coefficients for the variables obtained by totalling each column (types of interaction), and each row (purposes for interaction) of the Science Lesson Analysis System

Types of interaction columns	Generalizability coefficients
C1	0.73
C2	0.79
C3	0.74
C4	0.69
C5	0.92
C6	0.94
C7	0.91
C8	0.90
C9	0.91
Purposes for interaction rows	
R1	0.83
R2	0.98
R3	0.65
R4	0.90
R5	0.00
R6	0.88
R7	0.88
R8	0.80
R9	0.82
R10	0.80
R11	0.83
R12	0.75

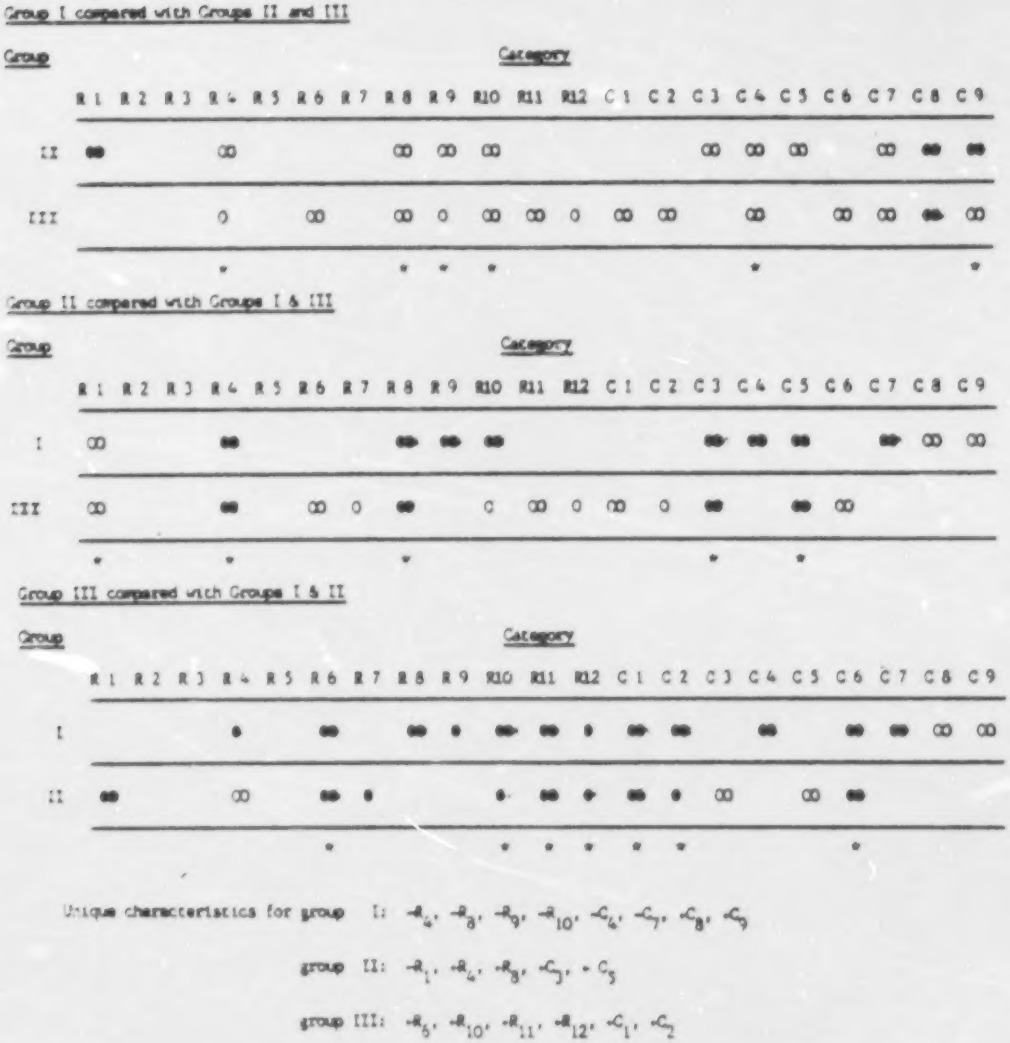
Table 3

Distribution of primary school levels taught by student teachers in the three primary science teaching style groups

Science teaching style groups	Primary School Levels											
	E.C.E years				Inter years			Senior years				
	1	2	3		4	5		6	7			
I Teacher-centred	4	3	8	15	7	8	15	3	4	7		
II Pupil-centred	2	5	8	15	7	3	10	3	4	7		
III Teacher-directed	5	2	5	12	4	9	13	1	5	6		

Table 4

The relative frequency of use of the twenty three categories of the Science Lesson Analysis System by the three science teaching style groups


Group I compared with Groups II and III
Group
Category
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 C1 C2 C3 C4 C5 C6 C7 C8 C9
II
III
Group II compared with Groups I & III
Group
Category
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 C1 C2 C3 C4 C5 C6 C7 C8 C9
I
III
Group III compared with Groups I & II
Group
Category
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 C1 C2 C3 C4 C5 C6 C7 C8 C9
I
II

Unique characteristics for group I: $-R_4$, $-R_8$, $-R_9$, $-R_{10}$, $-C_4$, $-C_7$, $-C_8$, $-C_9$

group II: $-R_1$, $-R_4$, $-R_8$, $-C_3$, $+C_5$

group III: $-R_5$, $-R_{10}$, $-R_{11}$, $-R_{12}$, $-C_1$, $-C_2$

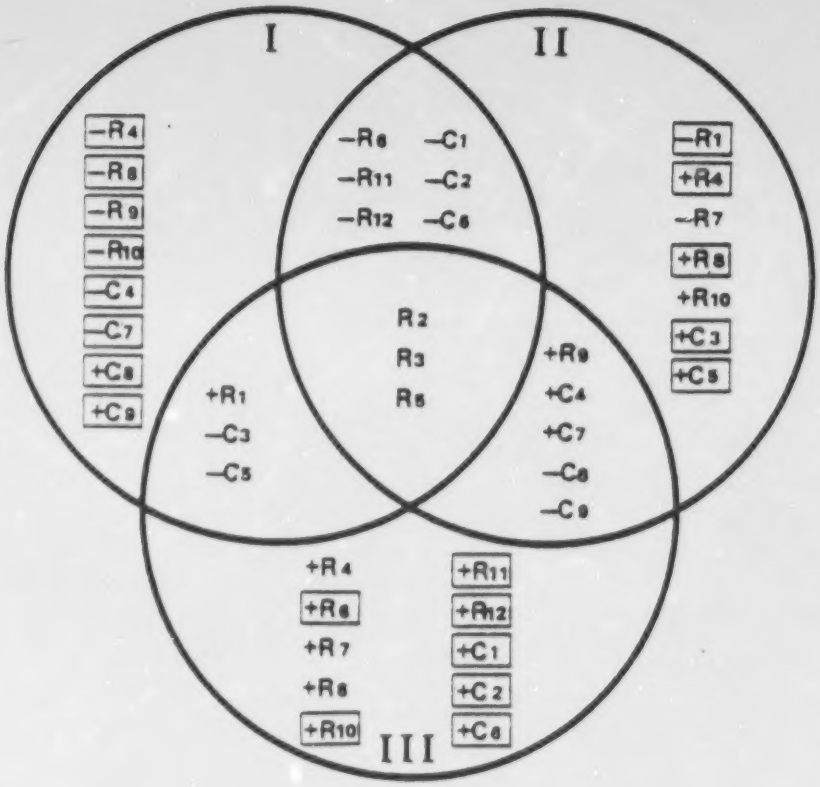


Figure 1 A Venn diagram illustrating the shared and unique characteristics of the three teaching styles

TIME AVAILABLE FOR TEACHING SURVEY (M. Crosbie)
(Abridged Report)

Background

1. During 1982 the Superintendents of Education (Science) in conjunction with the Research Branch initiated a "pilot" project to investigate the actual time available for teaching in a selection of Year 11 and 12 CSE/TAE science courses. For the "pilot" survey Biology and Chemistry were selected as the subjects while three senior high schools were selected at random and invited to participate in the project.

2. This survey was initiated following some years of concern by teachers of Year 11 and 12 Chemistry that the TAE syllabus was overcrowded for the teaching time available.

Aims of the Project

3. The aim of the project was to collect information for curriculum planners concerning the actual instruction time available within schools. A better appreciation of this factor should assist these planners to develop appropriate syllabi.

4. The aim of this "pilot" project was to establish

   (a) the feasibility of the proposed approach to collecting data,
   (b) the validity of the intended instruments, and

   (c) if there was a significant difference between the allocated teaching time and the "actual" time available for teaching" (TAFT-time).

Data Collection

5. At each of the three "pilot" schools four teachers (one for year 11 Biology, one for year 12 Biology, one for year 11 Chemistry and one for year 12 Chemistry) agreed to keep diary records for each lesson taken. To standardise data collection the sheet shown at Annex A was used.

6. A teacher of Chemistry year 11 at an independent school also agreed to participate in this project.

7. Diary sheets were forwarded to Research Branch at the end of each three week teaching segment and were held for processing until all returns for that term were available. Study of the first term data suggested that some teachers had misinterpreted an instruction resulting in them recording the allocated teaching time, rather than the actual teaching time, whenever the difference between these was less than ten minutes. All teachers were contacted and from the start of week 7 in term 2 all teachers recorded actual teaching time for each lesson.

Discussion of Data

8. Annex B Tables 1 - 6 show data for the 1982 school year for the senior high schools and the one class of a private school.

9. Table 1 shows data relating to the Timetabled Time per subject, after deducting public school holidays. It is often assumed that four hours per week is the time allocation per subject, eg Louden H W "Secondary Education Review: Special Problems in Years 11-12", (an address given 12th November 1982 at a Ministerial luncheon, p5), while the 1980 Certificate of Secondary Education and Tertiary Admissions Examination Syllabus Handbooks specified this requirement for thirteen (13) of the subjects listed.

10. Table 2 indicates the Australian average time per week allocated to subjects in government schools. Of the schools surveyed, the private school was close to both the Australian average, and the 240 minutes per week expectation. School A averaged as high as 235 minutes per week because Chemistry year 11 had a seventh period each week. The schools surveyed ranged from 200 minutes per week upto 235 minutes per week, with an average of 220 minutes per week for the three government schools.

11. Table 3 shows that of the timetabled time per subject, teachers recorded between 65% and 81% of that time as being "Time Available for Teaching" (TAFT-time). However in view of the comments made in paragraph 7 these percentages must be considered as over-estimates. (See paragraph 14 (b).)

12. In trying to identify how timetabled time was used other than for teaching, tables 4 , 5 and 6 have been calculated. Table 4 shows between 12.5% and 20.7% of timetabled time was used for examinations, study vacation and early dismissal of students (but the private school used only 9%).

13. Table 5 shows that only 1% to 2% of timetabled time was used for sporting carnivals by metropolitan schools (although country week participation increased the figure to 3% to 4.5% for the country senior high school). It is difficult to support the criticism offered by some teachers that too much time is lost to sporting carnivals. It could be that swimming carnivals in term 1 (with many public holidays) and athletic carnivals in term 3 (usually held close to a public holiday and a few weeks before TAE exams) are perceived by some teachers as the "straw breaking the camel's back".

14(a) Table 6 shows between 3.2% and 15.5% of timetabled time was used by teacher absence or lateness, staff meetings, school assemblies, plays, directed or private study, guest speakers, P A notices, camps, other subject excursions, early dismissals for sporting commitments, photos or allowing workmen to repair the room. Paragraph 7 above referred to a misunderstanding by some teachers which occurred during Term 1 and the first half of Term 2. The misunderstanding occurred in schools B and C, and doubling their percentages indicated would be a closer estimate of the actual time used, and allow more accurate comparison with schools A and X.

14(b)These adjustments would also REDUCE Table 3 (TAFT-time) percentages for schools B and C by approximately 5%.

Implications From This TAFT Survey

15. A sample of three government senior high schools and one class from a private school can not be considered sufficiently representative to allow prediction statewide, however the following statements are made:

a) For the government schools surveyed, time for exams, study vacation and early dismissal consumed about one-sixth of school time, (for the private school class, this figure was about one-eleventh) and this was about one half of the total time NOT available for teaching.

b) For the classes surveyed, between 21.5 and 33.0 equivalent weeks (of 240 mins/week) were available for teaching, with a mean of 26.3 weeks available for teaching.

Nature of School Timetables

16. a) School A was a metropolitan school with an eight period day (4 of 40 minutes and 4 of 35 minutes) with another 20 minutes daily for form period or 'USSR'. Each subject was timetabled for six periods per week, although a seventh period was given to one gridline and its subjects. Chemistry 11 received 7 periods per week.

b) School B was a metropolitan school with a five period day, with another 20 minutes of USSR per day. Teaching periods varied from 45 to 65 minutes in length. On one day per week, upper school students had a sixth early morning lesson before the rest of the school started. Each subject was timetabled for four periods per week.

c) School C was a country school with a six period day, with another 10 to 20 minutes daily for homeroom or "read-in". One day per week a seventh period occurred. Teaching periods varied between 45 and 55 minutes in length. Each subject was timetabled for four periods per week. Additionally students had five periods of directed study throughout the week.

d) School X was a private school with an eight period day (7 of 40 minutes, one of 35 minutes) with a 5 minute roll period daily. Each subject was timetabled for six periods per week.

17. Outcomes and recommendations include:

(1) It is doubtful if a closely monitored survey of a statistically representative sample of schools can be justified in terms of cost, manpower and any possible disruption to schools and students' learning (although the school A Chemistry 12 teacher has commented that the survey made him more aware of the way he used teaching time). It is not known whether a wider survey would significantly change this survey's findings.

(2) If the survey instrument were to be revised, instructions would need to be clarified to overcome the misrecording of "time available for teaching" referred to in paragraph 7.

(3) This survey took no account of students' time-on-task, (i.e. of the time available for teaching, how long were students carrying out learning activities), nor of efficiency of student learning habits. These two criteria could have more influence on student learning than "TAFT-time".

(4) Curriculum planners should note that between 45 and 55 weeks (240min/week) of teaching time might be considered available for the two years of Years 11 and 12 courses, (although considerable variation existed between schools), if the Year 11 and Year 12 figures for 1982 are summed for a two year course.

(5) Tertiary Institutions, in determining pre-requisite expectations of beginning tertiary students should be aware of the various demands on the allocation of school time.

(6) Schools should reappraise their priorities in terms of time allocation, to ensure an appropriate balance is maintained between academic studies (for those students for whom this is important) and other school activities.

(7) Further study may be warranted to validate the observation that the greater the variation from the traditional eight period day pattern in timetable structure, the less TAFT-time that is available.

(8) In the four schools surveyed, students were only "early dismissed" after the TAE or Term 3 exams. It is known that at least one metropolitan school encourages "early dismissal" by students each term, so the 12.5% to 20.1% of timetabled time (Table 4) is likely to be exceeded by this school. It may be interesting to establish how many schools encourage "early dismissal" and the time NOT available to teaching as a consequence.

Acknowledgements

18. The co-operation of the Principals and four staff in each of the three government schools, and of the teacher in the private school is acknowledged. Without their assistance this survey could not have been undertaken. The assistance of Research Branch in receiving and collating data is also acknowledged.

SUPERINTENDENT OF EDUCATION (SCIENCE)

TIME AVAILABLE FOR TEACHING (TAFT) SURVEY

SCHOOL: _____ TEACHER: _____

SUBJECT: _____ YEAR LEVEL: _____ TERM: _____

		Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
	Timetabled Session Time	—— mins	—— mins	—— mins	—— mins	—— mins	—— mins
Cycle/Week	Day of Week						
	Before/After Lunch						
1	Actual Time Available	—— mins	—— mins	—— mins	—— mins	—— mins	—— mins
	Reason for Time Loss (Use the codes set out below)						
Cycle/Week	Day of Week						
	Before/After Lunch						
2	Actual Time Available	—— mins	—— mins	—— mins	—— mins	—— mins	—— mins
	Reason for Time Loss						
Cycle/Week	Day of Week						
	Before/After Lunch						
3	Actual Time Available	—— mins	—— mins	—— mins	—— mins	—— mins	—— mins
	Reason for Time Loss						

CODES (Reason for Time Loss

A. Assembly
B. Class late
C. Unsettled from previous lesson
D. Staff meeting
E. Sports carnival
F. Excursion (other subject)
G. Examinations
H. Flexi-days
I. Other reason (please specify)

TABLE 1 - TIMETABLED TIME (LESS HOLIDAYS*)

School	Biol 11 Time/Yr	Biol 12 Time/Yr	Chem 11 Time/Yr	Chem 12 Time/Yr	School Average Time/Yr	Ave time per week
A - min	8810	8730	10425	8870	9209	234.9
B - min	8627	8875	8869	8875	8812	224.8
C - min	7610	7810	8140	7985	7886	201.2
Total - min	25047	25415	27434	25730	25907	660.9
Subject Average	8349	8472	9145	8577	8636	220.3
Equiv Wks (240 min/wk)	34.8	35.3	38.1	35.7	36.0	0.9

School X - 8650 mins
- 36.0 Equiv Wks
- 235 min/wk

* In 1982 Government schools were open for 40.6 weeks less 7 days for Public Holidays

(a) Labour day
(b) Good Friday
(c) Easter Monday
(d) Easter Tuesday
(e) Anzac Day
(f) Foundation Day
(g) "Queen's Birthday" /Show Day

Thus there were 39.2 effective school weeks.

TABLE 2 - TIME PROGRAMMED FOR SCIENCE PER WEEK (Average for Australian Government Schools).

(Extracted from "Science Learning Areas in Australian Schools", Commonwealth School's Commission, 1982, Appendix VII).

Subject	Biol 11	Biol 12	Chem 11	Chem 12
Time/wk (mins)	232.3	234.2	234.6	234.7

School	Biol 11 Time/Yr	Biol 12 Time/Yr	Chem 11 Time/Yr	Chem 12 Time/Yr	School Average
A - mins	6106	6062	7916	6109	6548
- equiv wks (240min/wk)	25.4	25.2	33.0	25.4	27.3
- % of Timetabled Time (Table 1)	69.3%	69.4%	75.9%	68.8%	71.1%
B - mins	6993	6494	6604	6356	6612
- equiv wks (240min/wk)	29.1	27.1	27.5	26.5	27.6
- % of Timetabled Time (Table 1)	81.1%	73.2%	74.5%	71.6%	75.0%
C - mins	5869	5666	6476	5155	5792
- equiv wks (240min/wk)	24.5	23.6	27.0	21.5	24.1
- % of Timetabled Time (Table 1)	77.1%	72.5%	79.6%	64.6%	73.4%
Total (mins)	18968	18222	20996	17620	18952
Subject Average Time(min)	6322	6074	6999	5873	6317
Equiv Wks (240 min/wk)	26.3	25.3	29.2	24.5	26.3
% of Timetabled Time (Table 1)	75.2%	71.7%	76.5%	81.6%	73.1%

School X - Chem 11 - 6963 mins
- 29.0 Equiv Wks
- 80.5%

TABLE 4 - TIME FOR EXAMS, STUDY VACATION AND EARLY DISMISSAL

School	Biol 11 Time/Yr	Biol 12 Time/Yr	Chem 11 Time/Yr	Chem 12 Time/Yr	School Average
A - mins	1250	1810	1315	1780	1539
- equiv wks (240min/wk)	5.21	7.50	5.48	7.41	6.41
- % of Timetabled Time (Table 1)	14.2%	20.7%	12.6%	20.1%	16.7%
B - mins	1078	1880	1308	1880	1537
- equiv wks (240min/wk)	4.49	7.83	5.45	7.83	6.40
- % of Timetabled Time (Table 1)	12.5%	21.2%	14.7%	21.2%	17.4%
C - mins	995	1520	1085	1745	1336
- equiv wks (240min/wk)	4.14	6.33	4.52	7.27	5.57
- % of Timetabled Time (Table 1)	13.1%	19.5%	13.3%	21.9%	16.9%
Total (mins)	3323	5210	3708	5405	4412
Subject Average Time(min)	1108	1737	1236	1802	1471
Equiv Wks (240mm/wk)	4.62	7.24	5.15	7.51	6.13
% of Timetable Time (Table 1)	13.3%	20.5%	13.5%	21.0%	17.0%

School X - Chem II - 780 mins
- 3.25 Equiv Wk
- 9.01%

TABLE 5 - TIME FOR CARNIVALS

School	Biol 11 Time/Yr	Biol 12 Time/Yr	Chem 11 Time/Yr	Chem 12 Time/Yr	School Average
A - mins	92	115	129	98	109
- equiv wks (240min/wk)	0.4	0.5	0.5	0.4	0.5
- % of Timetabled Time (Table 1)	1.0%	1.3%	1.2%	1.1%	1.2%
B - mins	113	111	105	187	129
- equiv wks (240min/wk)	0.5	0.5	0.4	0.8	0.5
- % of Timetabled Time (Table 1)	1.3%	1.3%	1.2%	2.1%	1.5%
C - mins	340	245	320	315	305
- equiv wks (240min/wk)	1.4	1.0	1.3	1.3	1.3
- % of Timetabled Time (Table 1)	4.5%	3.1%	3.9%	3.9%	3.9%
Total (mins)	545	471	554	600	543
Subject Average Time(min)	182	157	185	200	181
Equiv Wks (240mm/wk)	0.8	0.6	0.8	0.8	0.8
% of Timetabled Time (Table 1)	2.2%	1.9%	2.0%	2.3%	2.1%

School X - Chem II - 95 mins
- 0.4 Equiv Wk
- 1.1%

TABLE 6 - TIME FOR "OTHER"

School	Biol 11 Time/Yr	Biol 12 Time/Yr	Chem 11 Time/Yr	Chem 12 Time/Yr	School Average
A - mins	1362	743	1065	883	1013.3
- equiv wks (240min/wk)	5.7	3.1	4.4	3.7	4.2
- % of Timetabled Time (Table 1)	15.5%	8.5%	10.2%	10.0%	11.0%
B - mins	443	390	852	452	534.2
- equiv wks (240min/wk)	1.8	1.6	3.6	1.9	2.2
- % of Timetabled Time (Table 1)	5.1%	4.4%	9.6%	5.1%	6.1%
C - mins	406	379	259	770	453.5
- equiv wks (240min/wk)	1.7	1.6	1.1	3.2	3.2
- % of Timetabled Time (Table 1)	5.3%	4.9%	3.2%	9.6%	5.8%
Total (mins)	2211	1512	2176	2105	2001
Subject Average Time(min)	737	504	725	702	667
Equiv Wks (240mm/wk)	3.1	2.1	3.0	2.9	2.8
% of Timetabled Time (Table 1)	8.8%	5.9%	7.9%	8.2%	7.7%

School X - Chem II - 812 mins
- 3.4 Equiv Wks
- 9.4%

Note paragraphs 7 and 14a - Due to misunderstandings by teachers in schools B and C the times shown may need to be DOUBLED for comparison with schools A and X. If this is so then the school average % of timetabled time rises to 11.5%.

WESTERN AUSTRALIAN COLLEGE
SCHOOL OF EDUCATION
DEPARTMENT OF SCIENCE EDUCATION

PRIMARY SCIENCE TODAY

J D Rowe

An inquiry into the state of science in Western Australian primary schools, and into primary science teaching final year student teachers yielded some interesting and useful information. The need for information was highlighted by my involvement in the development of new courses in science education. My own perceptions, based on observations made as a practice supervisor and in the school based component of my courses, were unduly biased. Teachers and principals are usually guarded in their responses to college staff. Those schools most receptive to our need to work with children are often those aware of the limitations of their science programmes. (There are some admirable exceptions to this generalization.)

College students during an asistant teacher programme are in a very favourable position to collect information about schools. Their presence in the school is innocuous rather than disturbing and for parts of the programme they have considerable time and opportunity to observe the activity of the school.

A survey was conducted with a sample of 80 students, approximately half of the 1983 assistant teachers from the Mount Lawley Campus of the WA College. The students were from four of the eight third year groups. The four groups selected were those scheduled for science education lectures in the week immediately after completing their assistant teacher programme.

The subjects completed a 74 item questionnaire. Most of the items required either yes or no answers, or a numerical estimate. Much space was provided for additional optional narrative comment. The students were not required to identify themselves or the schools they worked in. There was no significant formal evaluation of the six periods of science education presented after the assistant teacher programme. The results of the survey are presented below.

Student Placement in Schools

The students were located in a wide variety of schools, large and small, metropolitan and rural, and government and private. They worked in some 156 classrooms distributed across all primary grades. Class sizes represented a typical spectrum for Western Australia.

Teachers' Involvement with Science

Student impressions suggest that of the 156 teachers that they were assigned to work with

81% (126) normally taught science to their classes

8% (12) of classes were taught science by another teacher

10% (15) of classes did no science

2% (3) no information given

Student estimates of the time that the teachers spent on science varied from

20 minutes-2 hours/week
average time - 55 minutes

Students were asked to comment on the type of science taught in each class. They suggest that

74% (98) of classes were involved with significant material based activity and inquiry oriented science

23% (32) of classes did mainly paper exercises or teacher exposition based science

4% (6) no information given

The estimate of 89% involvement with regular science was much higher than I expected. Students seemed to be quite confident about their estimates here. Only 11 students gave qualified answers about the teachers involvement, whereas some twenty gave additional narrative comment, such as references to teachers' programmes or materials that supported the estimates. Some of the data presented later supports these estimates.

An indicated allocation of time to science as 55 minutes per week suggests a nominal estimate based on the teachers timetable rather than a meaningful figure. Most students stated 60 minutes as the time involved.

Schools' Involvement with Science

Of the 80 schools in which the students were placed they suggest that in

78% (62) of schools science was taught to all classes

15% (12) of schools science was taught to some classes

7.5% (6) no information

When asked about staff concern for the value ofscience in schools:

35% (28) of students thought that science was important to teachers

42.5% (34) thought that science was not important to teachers

22.5% (18) no information

When asked about the principals' concern for primary science:

40% (32) of students thought that science was important

37.5% (30) thought that science was not important

22.5% (18) no information

Students observed in schools the following.

School policies for science	30% (24) of schools
Programmes for science	75% (60)
Science evaluation of science	35% (28)
Evidence for science being taught	84% (67)

The above data supports earlier claims that there is much science being taught in primary schools. Some of the data suggests that despite accepting a need to give some formal science instruction, many teachers are not very positive about their involvement. Narrative comments from thestudents also indicate that this is sometimes the case.

School Resources for Science Teaching

The following summarizes the information given by students.

Equipment	Good	21% (17)
	Some	15% (12)
	Very Little or None	45% (36)
	No information	19% (15)
Materials	Good	25% (21)
	Some	11% (9)
	Very Little or None	44% (35)
	No information	19% (15)

Curriculum Resources for Science

WA Education Department	64% (51)
WA Education Department and others	10% (8)
None	7% (5)
No information	28% (16)

Library Resources for Science

Adequate	49% (39)
Not adequate	5% (4)
No information	46% (37)

Facilities Available to Individual Classes

	Available	Not Available	No Information
Good access to outside areas	90% (72)	71/2% (6)	2.5% (2)
Access to a wet area or science room	51% (41)	46% (37)	2.5% (2)
In-class sinks	26% (21)	64% (51)	10% (8)
Power	95% (6)	4% (3)	1.25% (1)
Working space additional to desks	27.5% (20)	59% (44)	14% (11)
Storage	34% (27)	53% (42)	14% (11)
Garden space	58% (46)	34% (27)	9% (7)
Secure outside areas	19% (15)	77% (61)	5% (4)
Access to tools or workshop facilities	39% (31)	46% (37)	15% (12)

The above does not indicate a particularly good provision for a material or activity based science programme.

Student Involvement in Science Teaching

Of the 80 students in the survey

91% (73) taught science

Of the 156 classes the students taught

77% (120) received science lessons

The students taught a total of 530 lessons in 143 different topics.
This gives an average 4.4 lessons/class
3.7 lessons/topic.

Student Evaluations of Class Responses to Science Lessons

88% (106) positive

7.5% (9) qualified success

1.5% (2) negative

2.5% (3) no information

My initial reaction to this was that students did not teach enough science lessons or develop topics sufficiently. However when it is evident that one lesson per week or less is the norm and that students usually were in each class for only six weeks the figures are quite respectable. Narrative comments from students tended to be very positive.

Student Problems with Science

These figures are based on the 73 students who taught science.

Problems were related to

Programming	11% (8) of students
Materials	29% (21) of students
Classroom Control and Organisation	26% (19) of students
Storage of Materials	30% (22) of students

The programming figure is probable low because very few of the students were required to programme in science.

Teacher Support of Student Science Lessons

The following data relates to the 120 classrooms in which the students taught science.

Teacher Assistance Provided in 67.5% (81) classrooms

Assistance with ideas for teaching	67% (80)
programmes	30% (36)
materials	49% (51)
classroom control and organisation	20% (20)

Student narrative comments suggested that the figures might have been higher except that assistance was not required. This applied particularly to programming and to classroom control. Narrative comments also in this area gave much support to the belief that the classroom teachers were actively involved in teaching science.

The students suggested that the teachers attitudes to science teaching affected them in the following ways.

50% (71)	positively
11% (13)	negatively
30% (36)	no affect

Student Use of Other Support

Student comments suggested that time and geographical proximity of

other resources was most important here. For example while 27% used college resources, some 45% used the more widely located regional centres. The assistance sought most commonly was materials, with ideas for lessons occasionally mentioned. Many students expressed an absence of dependence on resources outside the school, while many others strongly suggested that they needed to know more about available resources.

CONCLUSIONS

The survey suggests that some science is regularly taught in the majority of primary school classrooms. The type of science taught often tends to be concerned with activities, materials, and inqury. The majority of teachers are not enthusiastic about teaching science, perhaps because the physical resources are limited. Much of the teaching must be inspired by some sense of duty or external compulsion.

Most students in the assistant teacher programme are actively involved in teaching science. Despite difficulties they appear to be positive about their science teaching. Science tends to be a relatively small part of the teaching programming for most assistant teachers.

HOW WELL DO STANDARD PIAGETIAN PROTOCOLS ASSESS ABORIGINAL CHILDREN'S CONSERVATION BEHAVIOUR?: IMPLICATIONS FOR SCIENCE TEACHING

David F. Treagust and Ross Hastie

Science and Mathematics Education Centre
Western Australian Institute of Technology
Bentley, W.A. 6102

Introduction

The impetus for this paper arose out the second author's interest in examining the conservation behaviours of the children he taught in a Special Aboriginal school in the Goldfields region of Western Australia. The Piagetian protocols used to examine conservation behaviour of number, area, and weight were those described by Matthews, Phillips and Good (1971). During these one-to-one interviews with aboriginal children, it became apparent that many of the students encountered problems with the tasks. Based on the scoring criteria described by Matthews et al (1971), the majority of the nineteen aboriginal children, who ranged in age from eight to twelve, were classified as non-conservers on all tasks. This information was not in concordance with the interviewer's impressions from his observations of the children whom he taught each day. The results and attitudes observed while conducting these interviews cast serious doubts on the reliability and validity of the results of the task protocols.

In order to better address this problem, the authors reviewed the literature in cross cultural psychology relevant to conservation behaviour and subsequently modified the conservation tasks in order to overcome problems associated with both language and culture. This paper reviews relevant research dealing with the conservation behaviour of aboriginals, examines the need for protocol modification, and describes the methodology for modifying protocols to more validity determine conservation behaviours of aboriginal children. The results based on administering these modified protocols to a group of aboriginal children are briefly discussed. The paper concludes by considering the implications of these findings for teaching science to aboriginal students.

Background

During the past twenty years, considerable research has been published on the cognitive development of non-Western people (Dason 1972, 1974, 1977; Drinkwater, 1976; Fahrmeier; Heron 1971; Philp and Kelly, 1974; Ehindero, 1982; Price-Williams, 1962; Za' rour, 1971). Several studies have specifically been concerned with the cognitive development of Australian aboriginal persons (De Lacey, 1970; deLemos, 1969; Davidson 1979, Graham, 1982; S. Harris, 1977; J. Harris 1979; Kearins, 1976, 1981; Seagrim and Lendon, 1978). Most of this cross cultural research has been published in education or psychology journals or in text books as few studies have been

concerned specifically with the nature of cognitive development and its relationship to science instruction and science learning (Ehindero, 1982; Prince, 1968; Brown, Fournier and Moyer, 1977). This state of affairs especially applies to studies of cognitive development with aboriginal peoples. There are likely to be many reasons for this, the most obvious being the lack of access to aboriginal subjects by science educators and the fact that researcher's interests are not necessarily concerned directly with science teaching. Cross cultural Piagetian research over the past two decades, conducted with a particular interest for science educators, has been described by Adey (1982).

In almost all cases of cross cultural Piagetian psychology involving non-Westernised people, researchers have made slight adaptations to the classical Piagetian tasks in an effort to lessen the effects of cultural differences. However, there have been differences of opinion concerning the validity of these surface alterations of the task items (Ashton 1975; Berry, 1978; Goodnow, 1962). Seagrim and Lendon (1980) in their study of the cognitive development of aboriginals in central Australia, state their case against modifying task items so that they may be 'culture fair' or 'culture appropriate'. By not altering the task protocols directly they protect themselves against possible claims that their research is deliberately biased toward aboriginal subjects. Secondly, they claim that an inordinate amount of time would need to be spent developing and validating culture fair tests on aboriginal and white groups, culminating in tests that are only useful in specific localities.

The antithesis of this view point is made by Piaget who states (in Dasen, 1972) that cross cultural tests require ' ... free conversation and not standarization...' Further, Dasen (1972) explains the need for the flexibility of Piaget's methods and describes studies which show that when tested on appropriate (ie. familiar) material, no differences may be found between a Western and non-Western sample in conservation behaviour. de Lemos (1969) justified the alteration of the conservation task materials presented to aboriginals by noting that if achievement of concepts is dependent upon particular materials used in tasks, then Piagets's theory must be of limited validity. She argued that as long as the underlying logical processes are constant, any alteration of materials to increase the appropriateness to the subjects would still enable valid results of to be achieved.

The Need for Protocol Modification

An obvious point to consider is why standard Piagetian protocols should be modified when tasks are presented to aboriginal subjects. Previous research reveals seven areas of distinct differences between Western and aboriginal subjects which can negatively affect performance of aboriginal subjects on standard conservation protocols, rendering the results both unreliable and invalid. These seven areas are: a) the specific nature of aboriginal learning; b) the absence of verbalization in aboriginal communication, c) the difference in cognitive context and style between cultures; d) the nature of the language used in every day life; e) the interference caused by using two or more languages, one of which is

English; f) cultural and questioning factors; g) sense of purpose of the task. Each of these will be briefly discussed.

The specific nature of aboriginal learning is described by S. Harris (1977) as being largely non-scientific. In his research into aboriginal learning and cognitive development at Millingimbi in the Northern Territory, Harris observed that learning occurs through informal strategies such as personal trial and error, observation, imitation and real life performance, rather than practice in contrived settings with the goal to master skills that are content specific. The major difference between Western and aboriginal learning contexts is between formal and informal education (S. Harris, 1977, P.4).

The absence of verbalization in aboriginal communication and cognitive development has been noted by a number of authors (S. Harris, 1977; J. Harris, 1979; Graham, 1982). This factor assumes increased relevance when one considers the nature of Piagetian tasks and the importance placed on expression of verbal reasoning. Since the task items and language structures of unmodified protocols are unfamiliar, translation of mental reasoning into spoken English is extemely difficult for many subjects. Even when an interviewer is convinced that the child knows why he had made a particular decision, his mental reasoning may not be indicated by what he says. This phenomemon has necessitated other researchers to accept what may appear to be less than satisfactory explanations of subject's choices (Dasen 1972, de Lemos, 1969; Seagrim and Lendon 1980). Also related to an absence of verbal reasoning is the time taken in making a response. As people in aboriginal communities are rarely required to respond according to time constraints, within reason, students should not be made to respond too quickly during an interview.

A third difference affecting performance on conservation tasks between Western and aboriginal subjects is the difference in cogntive context and style between cultures. Similarly, many aboriginal children sometimes 'fail' in conventionally designed problem solving tasks. This is of prime importance when considering western cultured psychological tasks. It must be considered that a poor performance of aboriginal children but may be because the problem presented is foreign in terms of content, context, interest and/or motivation. Consequently, this makes it difficult for the children to perceive the nature of the actual problem. If the child cannot perceive what the problem is about, can it be said that the child is fully bringing his or intelligence to bear upon it? This would clearly appear as a most critical issue in cross culture studies.

A fourth area requiring researcher's attention concerns the nature of language used in everyday life. (Christie, 1980; Graham, 1982; Harris P, 1981) In an article on measurement in tribal aboriginal communities, P. Harris (1981) noted that aboriginal languages do not seem to have abstract terms equivalent to English terms such as 'length' and 'weight'. This does not mean that such concepts are not known or are unable to be discussed or understood, rather that learning and expressing these concepts verbally is

done in a different way. Similarly, Graham (1982) points out that when discussing such things as mathematical ideas, with aboriginal children, the language that conveys these ideas should be pursued, rather than the insistence on direct translation of the English language. de Lemos (1969) postulates that since precise terms expressing number, comparison and measurement are generally lacking in aboriginal languages, it is possible that language factors are important in attempting to account for the apparent late development of conservation concepts in aboriginal children.

A fifth area affecting protocol modification is concerned with speaking more than one language. When a person speaks two languages, the greater the difference in structure between the two languages, the greater the interference will be in task results. Thus, it seems probable that task questions which are aligned to the base language may produce results that are more valid and reliable. Indeed the differences between the English language and the language of the Western Desert people (the most common dialect being Ngaanyatjarra (nyun'u'durra) are many and complex (Berndt, 1979).

A sixth area of difference between aboriginal and non-aboriginal subjects concerns the use of and reasons behind asking questions. A considerable amount of task confusion can occur relating to questions. For example, the use of questions with more than one alternative such as 'Are there more red checkers, more black checkers or the same number of red and black checkers?', should not be posed to aboriginal children as they will usually answer simply 'yes' or 'no'. Subsequently it is difficult to ascertain to which alternative the child is referring? de Lemos (1966, p 257) encountered the same problem in her research. The posing of 'why' questions is also of little value, as aboriginal children haye little or no notion of the use of 'why' to mean 'for what reason', rather, the word 'why' has it's most understood meaning 'for what purpose?'. In Ngaanyatjarra there are two words, 'nyaaku' meaning 'why, what for?' (purpose), and 'nyaatanu' meaning 'why, as a result of what?' (reason). In English these two meanings are inferred from the context of the question, whereas unless otherwise stated, when 'why' is used with Goldfields aboriginal subjects, the immediate usage is 'for what purpose?'. An example to help clarify this important point was given by a subject during the task of conservation of weight using an unmodified protocol. After observing that the folded piece of foil sank in the water, the subject stated that it(the folded foil) was heavier. When asked 'why do you think so?' as per the protocol, the response was, 'So he (the folded foil) can sink', thus explaining the purpose of the folded piece being heavier.

A seventh area affecting the outcome of administering a task dealing with conservation behaviour, concerns the subject's sense of purpose, and familiarity with the task. Aboriginal children who do not sense a purpose, or have no latent or intrinsic interest in a task, are liable to disregard the task as not being particularly valuable. They do not often have the inclination to do the task for the sake of doing it, as is common amongst Western oriented subjects. This problem is more prevalent with the older subjects, who do not seem to have the equivalent desire to please as the less independent younger ones.

During the interviews with unmodified protocols, it appeared that most of the children viewed the unmodified tasks as having 'trick' answers which may be considered as a function of unfamiliarity and result in responses lacking reliability. Underlying these considerations is a degree of what Harris (1977) terms 'cultural conservatism'. The subjects are quite able to believe that changes can 'just happen', and are not necessarily brought about by manipulation of the environment and it's constituents. Thus, it could be theorized that if the subjects are uncertain about changes occurring to task items, even though the interviewer has not obviously added to or subtracted from them in the course of a task, it is possible that the subject could subconcioulsy remedy inconsistences by believing that changes can occur without observable manipulation.

It is with these seven areas of concern in mind, that the set of standard protocols used earlier were modified and administered.

METHODS

Subjects

Twenty children aged from eight to twelve were selected for the trialling of the modified protocols. This allowed a minimum of two children in the eight year old section (where numbers at the school were low) to a maximum of six in the eleven year old section. Each age group consisted of representatives from both sexes, and where possible, a mixture of children with various degrees of contact with European culture. Almost all children were fullblood aboriginals, and all attended primary school with varying degrees of regularity and success.

All children spoke non-standard English in school; examples of speech patterns are described by Kaldor and Malcolm (1979). Out of the classroom, non-standard English and the local aboriginal dialect, Ngaanyatjarra, are spoken interchangeably; all children are bi-lingual. The children attended a Special Aboriginal School, located on the Mount Margaret Aboriginal Reserve (for more information see Stanton, 1979). The reserve is situated in the arid semi - pastoral country of the North East Goldfields, and is located approximately 40 kilometres from Laverton, the nearest town. All the children, and indeed the whole community, are extremely transient, and travel many hundreds of kilometres per year visiting surrounding communities.

Materials

The standard Piagetian protocols for conservation of number, length, area, and weight (Matthews, Phillips and Good, 1971) and quantity (Piaget, 1974) were modified with regard to familiarity of materials and questioning techniques. The modifications were based on observations from early administration of the standard protocols for number, area and weight to a similar group of aboriginal children.

Protocol Modification to Facilitate Familiarity

For the Conservation of Number task, checkers appeared to be of little interest to the children being tested, as they have no cultural familiarity. An excellent homogeneous alternative was found in the seeds of the quondong tree, (Santalum acuminatium). These seasonal remains of the quondong fruit are uniform in appearance, easily handled, easily collected, very familiar, and indeed cause a good deal of excitement amongst the children when available. This high interest factor was seen as a most favourable aspect of their selection as a substitute for checkers.

For the Conservation of Length task, sticks or string were replaced with the very familiar 'story-lead' which is a length of flexible wire used universally throughout the region for telling 'stories' in the sand. Sticks were previously used for this purpose, but following the installation of power stations in communities, and the advent of coat - hangers, the length of wire has become the most common tool for 'illustrating' verbal stories. 'Story - leads' are extremely familiar to all members of an aboriginal community.

For the Conservation of Weight task, plasticene was replaced with 'damper', an uncooked flour and water mixture,used as food throughout the region. All children 'grow up' with damper, and are extremely familiar with it and it's properties. Thus, the children can relate to it and know of no 'magical' properties that it may have in the hands of an interviewer. It is very easy to use, being easily pounded and rolled into the shapes required in the task.

For the Conservation of Area task, the modified protocol was similar to the standard protocol with squares of cardboard being used to represent the grazing area, and two equal sized sheep made of plastic to represent the consumers. Because of their cultural importance, kangaroo models would have been used, but isolation made them unprocurable. However, the Eastern Goldfields is a pastoral area comprised of sheep stations, and the children are very familiar with these animals. 'Houses' were represented by 2cm wooden cubes decorated identically with windows and doors, and were easily indentified by the subjects.

For the Conservation of Quanitity task, two normal drinking glasses, of equal volume, one tall thin glass and one wide glass, were chosen for their lack of marking and relative familiarity. Enamelled mugs are the most used form of drinking utensils in the community, but could not be used as they are opaque. White sugar was chosen as the continuous substance due to its familiarty and the relative importance placed on it by the community.

Questioning in the Modified Protocols

One of the major factors that may influence the apparent late development of conservation amongst aboriginal children is the difficulty in language comprehension between child and interviewer. To enhance validity of the protocol, questions could be asked in the vernacular. However, this was not possible as the interviewer does not speak fluent Nyaanyatjarra, and the nature of the language is detailed and complex to learn, even if instructors were available. Those aboriginals in the community who do speak the language fluently lack sufficient education in the Western sense to understand and administer the tasks effectively.

All children involved in the protocol administration attend school where the instruction is in English. Thus, rather than attempt to completely re-write the questions in Nyaanyatjarra, an attempt was made to restructure the questions so that greater understanding would take place, and in the hope that the procedure would appear less alien and hostile to the children. Two local aboriginal women, fluent in Nyaanyatjarra and relatively fluent in English, were made aware of the aims and methods of the tasks and subsequently agreed to assist in the equivalent translation of the protocol questions. The translations were performed in the following the way:

*The Standard Question (SQ) is the English generally presented in the standard protocols.

*The Direct Translation (DT, is a translation of the standard question into Nyannyatjarra adhering as closely as possible to the former. This translation of the English question is as a person would attempt to state it in Nyaanyatjarra.

*The Possible Dialectic English Translation (PDET) is a 'retranslation' back into English as it would probably by used within the community.

In some cases, the changes through translation are very slight, and in other cases the global terms used seem relatively imprecise for example, 'big' for 'bigger'. However, the inherent concept is assumed to be identical.

Sample Protocol; Conservation of Length

This protocol illustrates the modification of the materials and the language when giving the conservation tasks. The possible Nyaanyatjarra equivalent (PDET) of the Piagetian questions were used in conducting the interviews. The key language translations are as follows:

Equivalent SQ: :Are these two storyleads the same length, or is one longer or shorter than the other?

DT: :Milpinti tirtu munda waarrkupla?
(Storylead still affirmative same?)

PDET: Are the storyleads the same?
(Which one is long/small?)

A full description of this modified protocol is shown in Figure 1.

Scoring Procedures

The subjects' responses were recorded during the tasks and individual scores were converted to a Piagetian classfication of either non-conserver, transitional or conserver. The criteria for classfication were relatively standard and follow the same lines as those used by de Lemos 1969). Children who show clear non-conservation, or inconsistencies that appeared to be due to random answering, were classified as non-conservers. Those children who showed a clear conflict between conservation and non-conservation were classified as transitional. Those who showed clear conservation which was usually justified by an adequate explanation were classified as conservers. Those children who may have shown some confusion at the beginning of tasks and appeared to be either non-conservers or transitional, but subsequently went on to show clear conservation with an adequate explanation, were also classed as conservers.

The students interviewed generally displayed a sense of keenness and interest in each of the activites, and seemed to thoroughly enjoy carrying out the tasks. While each subject was given no clues as to the relative 'correctness' of his/her responses, he or she was made to feel as secure as possible through social interaction, and the use of such non-leading terms as 'I see', and repetition of the subject's response. The children were given ample time to make their decisions: One particular boy took more than twenty minutes to ensure 'perfection' in equality of the weights of the two pieces of damper mixture! Care was taken to remove any distractors related to the task, such as extra quandong seeds, pieces of damper mixture, and so on. All manipulation of material by the interviewer was carried out in full view of the subject, and at a relatively slow speed so that no 'trickery' could be suspected. In this respect it was helpful to involve the subject as much as possible in the handling of the materials being used in the task.

Validity and Reliability of the Modified Protocols

A prime reason for undertaking this investigation was due to the doubtful validity and reliability of existing protocols which were initially used to determine cognitive processes involving conservation with Goldfields aboriginal children. It is the authors' contention that the modified protocols used in this investigation are examining the same processes and require the same criteria to be satisified as the previously used protocols described by Matthews et at (1977). Consequently, every effort has been made to ensure that the content validity of the modified protocols has not been reduced. Many researchers agree that the flexibility of Piagetian tasks allows for modifcations in the interviewing procedures.

Reliability of the modified protocols was measured using a test - retest procedure. Eight days after the completion of the initial testing with the modified protocols, one student was selected randomly from each age group, and re-tested on all five conservation tasks. In each case, there was no difference to the results of any student compared with initial results, regardless of age, sex, ability or item type. Thus the test - re-test reliability was found to be very high. Due to physical isolation inter-tester relability could not be ascertained.

Results and discussion

Table 1 contains data showing the results of interviewing aboriginal children from the Goldfields region of Western Australia to examine their conservation behaviour using both the unmodified and modified protocols. Only data showing conservation behaviour is recorded. By nature the aboriginals of the Western Goldfields area are transient, hence the subjects were not necessarily the same in each year group and the data do not directly compare subjects on modified and unmodified protocols. Rather, the data demonstrate conservation of subjects on conservation tasks. Three tasks only were used for the unmodified protocols-number, area and weight. The modified protocols dealt with conservation of number, area, weight, length and quantity.

As the nature of the categories is an ordinal scale and the samples are related, it is possible to compare these data using a non-parametric test, the sign test (Siegel, 1956, pp 68-76). The number of categories to be compared were those dealing only with the conservation of number, area and weight. In each case, the proportion of subjects conserving on these tasks was compared using the modified and unmodified protocols. The direction in the difference of conservation behaviour was noted, with a positive sign (+) indicating that a greater proportion of children conserved on the modified protocols than a the unmodified protocols; a negative sign (-) indicated the opposite. Using the sign test, the probability of there being statistical significance between the data from the modified and unmodified protocols was $P<0.001$. The implication is that the children conserved far superior on modified conservation tasks which accurately addressed both context and language familarity of the aboriginal subjects.

The outcome of this research was specifically of interest to science teaching and science learning of aboriginal subjects in the Goldfields regions. In the development of curriculum materials for use in schools over the past decade, the use of Piaget's levels of conceptual development have become more accepted and widely used. For example, the introductory note of the Education Department of Western Australia's Primary Mathematics Syllabus (1978) set out the stage of development according to Piaget, and the approximate choronolgical age at which each stage should occur. Also the Education Department of Western Australia's Primary Science Syllabus (1983) would presuppose the development of concepts at relative levels and ages in Piagetian order. Further, the development of conservation is seen as an important integral step in the transition to logical thinking and formal operational thought.

Consequently as aboriginal children bascially learn the same science curricula as their Western oriented counterparts, the former's achievement in science requires careful attention. It is hard to argue against the point that science should be taught in as relevant a context as is possible. As Adey (1982, p14) points out," at a much deeper level it is sometimes argued that people from different cultures have completely different ways of observing, of weighing evidence, and of drawing conclusions, and that the very nature of science in the curriculum should be modified accordingly." Adey (1982) goes on to say that this argument does not specify the kind of science that would be different for non-western peoples. However, it does seem to be the case that for aboriginal subjects, any science taught must contain aspects of familiarity of material and of language if the science to be taught is not to be seen as "trickery" and aboriginal students are not to be considered "poor" learners. Aspects relating to science which are pertinent to the modification of these protocols for conservation behaviour could easily be incorporated into the lessons for teaching science to aboriginal children. The subsequent knowledge and attitude toward learning of aborignal children is likely to be much improved.

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TABLE 1

Number and Proportion of aboriginal subjects conserving on modified and unmodified Piagetian Conservation Tasks

Age in years	No. of Subjects	Conservation Task				
		Number	Length	Area	Weight	Quantity
8	2[a]	1(.5) (+)[c]	0	1(.5) (+)	2(1.0) (+)	0(.0)
	5[b]	1(.2)	-	0(.0)	0(.0)	-
9	5	4(.8) (-)	2(.4)	2(.4) (+)	3(.6) (+)	3(.6)
	3	3(1.0)	-	0(.0)	0(.0)	-
10	4	3(.75) (+)	3(.75)	3(.75) (+)	3(.75) (+)	3(.75)
	4	1(.25)		1(.25)	0(.0)	-
11	6	5(.84) (+)	4(.66)	2(.33) (+)	4(.75) (+)	3(.66)
	4	2(.50)	-	1(.25)	0(.0)	-
12	3	3(1.0) (+)	3(1.0)	3(1.0) (0)	3(1.0) (+)	3(1.0)
	3	2(.66)	-	3(1.0)	0(.0)	-

Notes a. Number of subjects administered the modified protocols

b. Number of subjects administered the unmodified protocols

c. Direction of difference for proportion of conserving subjects per task at each year level

Two story-leads of identical length and nature are shown to the child and there is general informal discussion about their use and interest to the children. The two story-leads are then placed on the table in front of the subject and the task begins. (Story-lead = SL)

	T	S's response
1.	(SLs are placed on the table in front of S, ends matching and approximately 3-4cm apart, so that equality of length is easily recognizable. T may even pick up the SLs together to show S that they are identical). "Are these SLs the same?"	"Yes" or some type of affirmative gesture.
2.	"Are you sure?"	As above. Subjects are free to physically manipulate SLs.
3.	(Either or both of the following questions may occur). "All right, I'm going to move this SL like this." (T moves one SL laterally some 15-29cm to the right.) "Are they the same (pause) or is one long?"	"No" (during pause) or "one long" or similar.
	and/or "Let's pretend a little ant has to walk all the way along this story-lead and another little ant has to walk all the way along this one. Has one ant got more to walk than the other (pause) or same?"	Usually "He got more" or "this one long one" or similar.
	** If S's response indicated conservation at step 3, discussion as at step 11 following would occur.	
4.	"Which one is long/more?"	
5.	"What makes that one long?" or "How do you know that one is long/more?"	"It's long one" or "You moved it" or "It's more to go" and similar responses.
6.	"I see. Help me put them the way they were before."	T and S arrange SLs as at step 1.
7.	Repeat steps 1 and 2.	
8.	O.K. I'm going to move this one now." (Move second SL laterally some 15 to 20cm to the left). (Carry out questioning as at step 3.)	Responses as for step 3, but usually refer to second SL.
10.	"Thank you S. Will you put these away while I get this ready?"	S packs away materials while T notes scores and so on.
	** If S's response showed possible conservation at step 3, the following discussion would occur.	
11.	"How do you know that they're the same?" or "Can you tell me how they're the same?" or "What makes it the same?"	A variety of responses may ensue: "Still same" or "Same but you just (only) moved it" or "Same before."
	The same questioning occurs at step 8 . End of task.	

Modified Protocol for Conservation of Length

Figure 1

STUDENT ENGAGEMENT IN SCIENCE LEARNING TASKS

Kenneth Tobin

Western Australian College

Learning science process skills has been a desired outcome of primary and secondary science curricula for many years. Initial approaches to process skill teaching were influenced by Science - A Process Approach (SAPA) (1975, 1967) which introduced eight basic processes in grades K-3 (observing, classifying, using numbers, measuring, using space-time relations, communicating, predicting and inferring) and five integrated processes in grades 4-6 (controlling variables, defining operationally, interpreting data, formulating hypotheses, and experimenting). Later approaches to process skill teaching (e.g. Tobin and Capie, 1982a) classified processes according to function in terms of investigation planning, data collecting and data processing skills. Process skills are not separated from science content when problems are encountered in real life situations. However, in classroom contexts it is often convenient to isolate the processes so that activities can be programmed to enable students to have intensive practice on the skills. Once learned, the skills can be applied, as required, to solve problems in and out of the classroom. Science, social science and mathematics are among the school subjects that purport to develop inquiry/process skills by having students plan investigations and then collect and analyze data. Because of the potential generalizability of process skills it is not surprising that

several research groups have endeavoured to identify effective teaching and learning strategies.

A considerable amount of research has been directed toward the task of improving student achievement in materials centred science activities. Among the variables likely to influence learning is the time allocated to learning tasks. This fact is generally recognized by teachers at all levels and often manifests itself in competing requests for allocation of a greater proportion of school time which is usually a fixed resource. Carroll (1963) distinguished between opportunity to learn and engagement. Opportunity to learn may be viewed in terms of the amount of time budgeted by the system or teacher for learning activities. However, engagement, or time on task, cannot be viewed in this way since it is related to the amount of time that a learner is intellectually involved in an activity. Several studies reported that the proportion of time in which students engage has a positive and predictable relationship with student achievement (e.g. Hecht, 1978; Ladaherne, 1968; Samuels and Turnure, 1974) while other research confirmed a link between student engagement and teacher performance (e.g. Tobin and Capie, 1982b).

QUALITY OF STUDENT ENGAGEMENT

Two categories of engagement have been defined. Bloom (1980) described overt engagement in terms of doing assigned work or in some way responding in a relevant manner to instruction and the instructional material. If student task involvement is overt, participation can be directly observed. For example, overt engagement might involve discussion,

manipulation of materials, writing, drawing or graphing. Students can use process skills overtly to formulate responses to questions, to justify points of view, to explain events or procedures and to interpret or describe results. Covert engagement was described by Bloom as thinking in relevant ways about what is going on in the classroom. Science process skills may be used covertly as students attend to the teacher during instruction, contemplate the plan of an investigation, or consider how a graph is to be interpreted.

The type of task allocated by the teacher and the way in which the classroom is organized can often determine whether student involvement is overt or covert. For example, most of the data collecting tasks prescribed for middle school classes are concrete in nature. Accordingly, students are able to engage in an overt manner as data are collected. However, in comparison to data collecting tasks, engagement in investigation planning and data processing tasks is often covert. Engagement in such tasks can be overt if students discuss plans with others, write procedures to be followed, calculate a scale for a graph, represent data in a graph or diagram, and write generalizations from the results of an investigation.

Initial time on task research pooled across the variety of tasks prescribed by teachers during a lesson. Although significant relationships were obtained between time on task and science achievement (e.g. Dillashaw and Okey, 1983) the implications for teaching and curriculum design were not substantial. The results supported the common sense notion that students learn more when they behave as the teacher intended. The research did not address the hypothesis that engagement in some tasks would be more

fruitful thatn engagement in other tasks. Furthermore, a distinction was not made between overt and covert engagement.

Three related studies did differentiate both the types of tasks in which students engaged and whether engagement was overt or covert. The results of these studies are discussed below.

REVIEW OF ENGAGEMENT RESEARCH IN SCIENCE EDUCATION

In a study conducted in 13 middle school classes in grades 6, 7 and 8 in Georgia (USA), Tobin and Capie (1982b) reported that teaching behaviours had direct and indirect effects on student achievement. Clear teacher questioning was associated with higher student engagement rates and use of an extended teacher wait time enhanced summative achievement and retention.

When teachers allocated time for planning and data processing related tasks three trends were evident: more than fifty percent of the time students were covertly engaged; students were off task for approximately thirty percent of the time; students engaged in recalling behaviours for five percent of the time; and students engaged in overt planning and generalizing tasks for only two percent and five percent of the allocated time respectively.

The proportion of attending and generalizing were each significantly related to process skill achievement. Students who attended to instruction tended to achieve at a higher level than those who did not. Similarly, those pupils who exhibited higher rates of generalizing behaviour also

tended to attain higher achievement scores. The statistical significance of attending raises a question on the relative importance of overt and covert student engagement. Since the frequency of occurrence of several of the engagement modes (e.g. planning) was close to zero, the principal means of engaging in those categories was covert through the attending mode. By rating the predominant teacher behaviour during the same time interval in which pupils were rated, the allocated task to which students were attending was recorded. Thus for each engagement mode a covert and overt measure was available for each student. When total engagement was considered (overt plus covert), comprehending, planning, and generalizing were each significantly related to summative achievement and retention. These results supported the hypothesis that appropriate practice on the instructional objectives results in higher student achievement.

The study conducted by Tobin (1983a) with students from fifteen Western Australian middle school classes was concerned with relationships between types of student engagement, process skill achievement and student perceptions of the learning environment. Each class participated in eight process oriented science lessons in a two week period. Somewhat different results were obtained as far as student engagement was concerned. Student engagement was not related to process skill achievement. This may be due to a ceiling effect for engagement in the study. An average time on task of 90 percent was high compared to the 63 percent reported by Tobin and Capie (1982b). A relatively small standard deviation in conjunction with the high mean value for student time on task are possible explanations for the null relationship between student time on task and achievement. A linear relationship between student engagement and achievement was not

apparent for the range of time on task that occurred in this study (88 to 100 percent), whereas a significant relationship was reported by Tobin and Capie (1982b) when engagement varied over a wider range (5 percent to 98 percent). The results also indicated that students who participated in overt planning and data collecting tasks tended to obtain higher achievement scores than students who did not engage in this manner. The proportion of student attending was not significantly related to achievement in the study. Unlike the study reported by Tobin and Capie (1982b), wait time was not manipulated. As a consequence, classroom discourse was likely to be characterized by rapid fire teacher questioning and short student responses. In such circumstances, attending to the teacher was unlikely to be as beneficial as attending to a teacher in long wait time classes.

Although teachers appropriately distributed the total time for investigation planning, data collecting and data processing tasks, students were predominantly engaged in an overt manner only when data were collected. Students were engaged in a passive attending mode for 37 percent of the allocated time. This result reflects the way in which classes were organized. Typically, teachers utilized a whole class setting for investigation planning and data processing tasks. One promising note from the study was that covert engagement decreased and overt engagement increased significantly during the sequence of eight lessons. This result suggests that the proportion of covert engagement might decrease as students develop the skills to needed to work autonomously of the teacher.

The purpose of the study conducted by Newton and Capie (1982) was to

further investigate relationships between student engagement in a range of tasks and process skill achievement. The study involved twelve students in each of eight intact middle school science classes in Georgia (USA). A sequence of six science lessons based on process skill objectives was presented over a two week period. While all eight teachers received the same set of objectives, the lesson plans contained activities and procedures designed to promote engagement on planning or data processing tasks.

Student planning, data collecting and data processing were significantly correlated with process skill achievement. These results suggest that there should be greater emphasis on student focussed engagement modes such as planning and data proocessing which are significantly related to achievement but occur for less than three percent of the instructional time. Conversely, continued use of frequently occurring engagement modes that yield low correlations with achievement should be reviewed. The results indicated that student planning, data collection and data processing are important and should provide a focus for science lessons.

The three reviewed studies have several significant similarities and one important difference. In each case overt engagement in certain tasks were related to process skill achievement. Those concerned with curriculum design and implementation can plan and conduct science activities so as to increase the time allocated for overt engagement in investigation planning, data collecting and data processing tasks. The studies (Newton and Capie, 1982; Tobin, 1983; Tobin and Capie, 1982b) indicate that teachers allocated

sufficient time for planning and processing tasks, however, student engagement tends to be covert while attending to the teacher in whole class settings. Teacher education courses and curriculum guides should provide precise suggestions of activities to enable students to engage in an overt manner in planning and processing tasks. The results of the studies suggest that teachers should maintain a learning environment in which students can overtly plan investigations, collect data and interpret the findings. Newton and Capie also reported that overt student planning and data processing levels were enhanced with the use of lesson plans, model analysis and performance feedback. This outcome raises the possibility of substantially increasing overt engagement on these engagement modes in order to enhance achievement. Although the results of the studies indicated ample opportunity to accomplish such an increase by decreasing the incidence of off task behaviour, teachers might find this difficult to accomplish. Changes may be required to the way teachers seek to engage students. For example, rather than having one student extrapolate from a graph while others in the class attend, a preferable procedure might require all students to provide a written extrapolation from the graph. In this way all students are able to engage in an overt rather than a covert manner. Supervised seatwork or small group activities might also be encouraged to enable a higher proportion of students to actively engage in investigation planning and data processing tasks.

There is no clear guidance on the effectiveness of covert engagement. Tobin and Capie (1982b) reported that attending to the teacher was positively related to process skill achievement. In contrast, Newton and Capie (1982) and Tobin (1983a) reported that teacher focussed engagement

was not related to process skill achievement. This apparent anomoly may be related to the classroom learning environment that prevailed in the different studies. Support for this interpretation was provided by the Tobin and Capie (1982b) study in which teacher wait time was extended. Possible effects of wait time on overt and covert processes are further explored in the following section.

IMPROVING THE QUALITY OF CLASSROOM PROCESSES

Theoretically, time on task appears to be a necessary yet insufficient condition for learning in classrooms. Slavin (1982) suggested that other variables need to be considered in time on task research. For example, variables related to the nature and quality of the tasks in which students engage are also likely to be related to achievement. Recently, researchers commenced investigations of cognitive processes as mediators of teacher behaviour and student achievement. The stimulus for this research emanated from Doyle (1975) who argued that a major weakness of the process-product paradigm was that it focussed only on student behaviour and ignored covert responses during classroom instruction. Doyle presented a paradigm for classroom research that focussed directly on the processes that mediate between instructional stimuli and learning outcomes. Winne and Marx (1983) stated that classroom researchers should consider internal processes of students in classrooms and should focus on the student as an information processing learner. They stated that for learning to occur the student must: perceive the instructional stimuli; note their occurrence; understand the cognitive processes that are required; use the processes to create or manipulate information to be stored as learned material; and encode the

information for later retrieval. If these criteria are accepted as valid, teaching roles can be defined in terms of maintaining appropriate student task involvement and utilizing cues to stimulate the cognitive processes deemed necessary for learning.

Tobin (1983b) attempted to establish links between teacher wait time, teacher and student discourse and student achievement. The study involved students from twenty intact classes at grade 6 and 7 level in Western Australia. Teacher wait time was manipulated in the study. Ten teachers were randomly assigned to a wait time feedback group and ten teachers were assigned to a control group that received placebo feedback. All teachers in the study were provided with seven lesson plans and class sets of the required materials. The lessons were designed to develop concepts related to probability. Each lesson commenced with a materials centered problem to be solved by students. Through direct involvement in planning how to solve the problem, collecting data and interpreting the results, probabilistic concepts were introduced and applied. The study was stimulated by the suggestion that there was no relationship between teacher wait time and overt student engagement on specified learning tasks (Tobin and Capie, 1982b).

The results indicated that achievement was higher for wait time feedback group classes than achievement for control group classes. The results suggested that teachers in the wait time feedback groups used the additional time to formulate discourse that required students to respond at greater length and react to responses of others. Such student discourse appears to be beneficial for the results indicated that the average length

of student discourse and the proportion of student reacting were significantly related to achievement. Differences between wait time feedback group teachers and control group teachers included: the average length of student discourse was greater in wait time feedback group classes; the average length of teacher discourse was less in wait time feedback group classes; the number of utterances was less in wait time feedback group classes; the proportion of teacher soliciting was greater in wait time feedback classes; the number of solicitations per unit time was less in wait time feedback group classes; the proportion of teacher reacting was less in wait time feedback classes; the proportion of teacher structuring was greater in wait time feedback classes; the proportion of teacher mimicry was less in wait time feedback classes; and the proportion of teacher probing following student responses was greater in wait time feedback classes.

There will be times in most science lessons when a whole class activity structure is most appropriate for the tasks to be undertaken. On the basis of the findings reported by Tobin (1983b) the following strategy is suggested to maximize student task involvement during a whole class activity structure.

1. A question is clearly presented at a relevant time during the lesson.

2. All students are given three to five seconds of silence in which to consider a response.

3. One student is called on to respond to the question.

4. The student is provided three to five seconds to commence a response before the question is repeated, rephrased or redirected to another student.

5. After a student has responded to a question, three to five seconds are provided for the student to commence to elaborate or evaluate the response and for others in the class to consider the appropriateness of the response.

6. The question or the response is redirected to another student in the class.

The purpose of the above strategy is to ensure that the quality of covert engagement is maximized for the majority of the students in the class. By asking a question before calling on a student to respond the payoff is high for students to listen to the question and formulate a response. The purpose of the pause between the question and the teacher calling for a response is to allow time for cognitive processing by the students and to enable the teacher to consider an alternative course of action if the question is not answered. After calling for a response, time needs to be provided for the student to commence an answer. Once an answer is commenced, however, cognitive processing continues. As a consequence, elaborated responses are often delivered as bursts of speech, with each burst separated by a pause that often exceeds three seconds. Pauses of this duration

provide ample opportunity for an unwary teacher, or another student, to interject and assume control of the discourse. This course of events may deprive the initial respondent the opportunity to fully develop an answer or to self evaluate the adequacy of a response. If there was value in asking a question in the first place, then the student should be provided with reasonable time to respond in an appropriate manner. When a student response is completed there is often value in directing the response to another student for evaluation or elaboration. Similarly, questions that are initially unanswered can be redirected to others in the class for a response. Knowledge that a question or a response will be redirected for additional discussion increases the payoff for students to listen to one another.

FOCUSSING STUDENT ENGAGEMENT

An important outcome of activity oriented science programs in middle and high school grades has been autonomous solving of real life problems. However, in an endeavour to provide essential support to science teachers, curriculum designers and textbook authors may have inadvertently increased the incidence of "cookbook science". Recent evidence of this trend was provided by Yeany and Roadrangka (1983). The results indicated that rather than becoming directly involved in investigation planning activities the students followed the directions of a recipe in laboratory work. Such activities do not provide students with opportunities to practise the skills needed to plan an investigation. As a consequence, many students would experience

difficulties in solving real world problems for which recipes are rarely available.

Research suggests that if students are to learn to plan investigations they should have direct experience with the types of reasoning involved when planning occurs and should be provided with opportunities to develop the required skills. Of course the specific skills required to plan an investigation are dependent on the nature of the problem to be solved. The Investigation Planning Observation Guide (IPOG; Capie and Tobin, 1980) was developed to apply to problem solving situations where measurement and manipulation are required. Four sets of operations are involved in the investigation planning phase: generating questions; controlling variables; defining operationally; and preparing a data table. Each IPOG task is described in Figure 1.

When an investigation has been planned students can implement the plan and collect the data needed to solve the problem. Subsequently, the data are manipulated and interpreted to find answers to the problem, decisions are made on whether the investigation needs to be repeated with a modified plan, and further problems to be investigated are identified.

Data collecting in science lessons can involve observation and measurement. Observation using the senses results in qualitative data while measurement results in quantitative data. Common measurement types that frequently occur include length, area, volume, mass, force,

Operation	Component
Generating questions	Naming the responding variable in a question of interest.
	Identifying and naming variables that may affect the responding variable in an investigation.
	Formulating a hypothesis relating a variable to the responding variable of interest.
Controlling variables	Distinguishing between variables that are to be held constant and those that are to be manipulated in an investigation.
	Identifying procedures to hold selected variables constant in an investigation.
	Demonstrating ways to hold variables constant in an investigation.
Defining operationally	Constructing an operational definition of the manipulated variable in an investigation.
	Demonstrating procedures for measuring the manipulated variable in an investigation.
	Constructing an operational definition of the responding variable in an investigation.
	Demonstrating procedures for measuring the responding variable in an investigation.
Preparing	Preparing a table for recording data.

Figure 1. Investigation planning

time and temperature. Quantification also occurs when frequency counts are taken in activities such as the number of cars passing a particular point, the amount of roadside litter, the number of ants surrounding different types of food, etc.

Two sets of data processing objectives can be distinguished: data manipulation; and data interpretation. The Data Processing Observation Guide (DPOG; Yeany and Capie, 1979; see Figure 2) can be used to plan and focus student engagement in data processing tasks.

Teachers do not intuitively implement lessons to provide students with opportunities to practise planning and data processing tasks. In fact the studies reviewed in this paper suggest that overt student engagement in such tasks is far too restricted. Apart from familiarizing preservice teachers with planning and processing tasks in which students should engage, strategy analysis procedures can be utilized to address problems associated with effective implementation. Using strategy analysis, teachers can develop a thorough understanding of investigation planning and data processing tasks and formulate strategies to present tasks in an appropriate order and provide students with opportunities to practise each task.

The planning and data processing models provide a structured approach to planning and implementing materials centred science. The listed cognitive tasks can be used in model analysis in staff development programs and as a checklist for planning lessons to ensure that students are provided with appropriate experiences for learning

Operation	Component
Data manipulation	Recording data in a table, chart, diagram or sketch
	Ordering or estimating data from an investigation
	Condensing or grouping data from an investigation
	Preparing the axes from a graph
	Plotting or displaying data in graphical form
Data interpretation	Translating data from a graphical to a verbal form
	Expanding by using data to extrapolate or interpolate
	Comparing data that have been collected
	Inferring from data that have been collected

Figure 2. Data processing

how to plan and conduct investigations. An inevitable question that is raised about any model relates to limitations of its application. In this case the model is generically applicable to activity oriented science. It is difficult to envisage any science investigation in which investigation planning, data collecting and data processing are not involved. However, tasks may not be included, depending on characteristics of a specific investigation. For example, the IPOG was formulated with quantified variables and manipulation in mind. This is not to suggest that all science activities need to include quantitative data or manipulated variables. If qualitative data are collected, or a variable is not manipulated, certain of the investigation planning steps will not be included when lessons are planned or implemented. If this is the case, the data processing phase will also need to be modified.

Research in science classrooms suggests that learning is most effective when students are directly involved in the tasks to be learned. As a consequence, there are advantages in planning and implementing science activities in a manner that provides all students with opportunities to plan investigations and process data. The IPOG and the DPOG provide a means of planning lessons that focus on investigation planning and data processing tasks. To many science teachers the models may appear to be an imposing structure to place on science lessons, however, the structure simply provides an ordered set of tasks that need to be completed in materials centred science investigations. Each task provides students with opportunities to make their own decisions on how to plan an activity.

RESEARCH NEEDS

Compelling reasons for measuring student engagement relate to the potential influence of the variable on learning. Despite the intuitive appeal of the argument that students learn when they are directly involved in what is to be learned, additional research is needed to improve the quality of science teaching. The studies reviewed in this paper indicated that engagement in certain tasks tends to enhance achievement while engagement in other tasks does not. Additional research based on global conceptualizations of student engagement is unlikely to assist practitioners. The research that is needed should incorporate distinctions between categories of tasks in which students engage, the group structure in which the tasks are embedded and specific details on the nature of the engagement. For example, a distinction needs to be made between a student who recalls information during a whole class structure in the planning stage of an investigation and a student who evaluates the adequacy of a peer response in a work group while planning an investigation.

Research has indicated that overt engagement in specific learning tasks can enhance achievement. Yet the covert engagement that precedes overt student engagement and occurs concurrently with it influences the quality of engagement and learning. Research should be directed toward identifying the types of student thinking that occur in process oriented science activities. In order to investigate hypotheses related to student thinking, different methodologies will

be needed to measure engagement. Results of research involving observer judgements of student task involvement have provided some insights into the most appropriate tasks in which students should engage during science lessons. However, such research tends to over simplify learning in classrooms. Students can be regarded as multi channel analyzers capable of simultaneous cognitive and affective processing. Whilst it might be desirable to concentrate thinking on the tasks prescribed during instruction, learners will inevitably be involved in a number of cognitive and affective thoughts during a lesson. For example, a student might be actively plotting points on to a graph and simultaneously thinking how nice it will be when the task is completed. Since thinking is an internal process, direct observation is not an appropriate procedure for measuring types of covert engagement.

Three procedures appeal as being most suitable. A thinking aloud technique whereby students are asked to report on their cognitive processes as lessons are implemented is a technique that is likely to provide suitable data. Although the technique is obtrusive, the close proximity of the classroom event to the stimulus to recall should enable high quality data to be obtained. An alternative is a stimulated recall technique whereby students are shown a videotaped replay of a recent lesson and are asked to recall what they were thinking at selected locations during the lesson. A third technique is to ask students to report on their engagement on a questionnaire administered immediately after a lesson or at selected locations during a lesson. There are obvious advantages and disadvantages

associated with the use of each of the above procedures. However, each appeals as potentially suitable for answering types of research questions on cognitive and affective processing in science classes.

Cognitive and affective processing of teachers is also an area that needs to be researched. During process oriented science lessons teachers are required to make a large number of managerial and instructional decisions. Presumably, teacher behaviour in science lessons is closely related to the quality of the student engagement that occurs. If teacher thinking is directed toward formulation of appropriate instructional strategies teachers can influence student cognitive processing and thereby enhance the quality of overt engagement and increase achievement. Within this framework the use of an extended wait time appeals as an important instructional variable. For example, research is needed to provide insights into the manner in which the use of an extended wait time is able to influence the quality of classroom environments and student learning. From a theoretical perspective the provision of longer pauses between speakers should enable teachers and students to process information pertinent to instruction. When higher cognitive level outcomes are concerned, teachers and students should utilize pauses of up to five seconds duration for relevant cognitive processing. However, in classes where a regular wait time is utilized, necessary cognitive processing might not occur and the quality of teacher and student discourse could suffer accordingly.

CONCLUSION

The results of the research reviewed in this paper suggest that process skill achievement can be enhanced for all students by increasing the time in which they engage in planning, collecting and generalizing tasks. Science curriculum designers and teachers should ensure that students are provided with opportunities for sustained engagement on each of these tasks. This will necessitate student involvement in small group and individualized settings. There will also be times when whole class instruction is desirable. On such occasions teachers should use extended wait time and redirecting strategies to ensure that students are provided with time to undertake the cognitive processing needed to understand what has been said or to formulate a response to a question or a direction.

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BEYOND THE KELLER SCHEME

Philip Jennings. School of Mathematical and Physical Sciences,
Murdoch University, Murdoch 6150

ABSTRACT

The application of the Keller scheme to University physics education is reviewed. The strengths and weaknesses of the scheme are discussed together with modifications which have been found effective in various courses. It is concluded that the Keller scheme is not a general approach to tertiary teaching but a model on which successful courses can be built in appropriate circumstances.

The Keller Scheme

Self-paced learning and individualized instruction have a long history in tertiary education in the form of reading courses and small group tutorials. However in 1968 Fred Keller put forward a comprehensive proposal, based on behaviourist psychology. to integrate these themes into a general method of instruction. This became known as the Keller scheme and it is characterized by eight major features.

(1) The course content is divided into a large number of modules or units. Each unit is approximately one week's work at the normal rate of study for the course.

(2) A comprehensive study guide is prepared for the course. This contains general aims of the unit, specific learning objectives, references to text books and notes. questions, exercises and experiments to perform.

(3) Students are permitted to work through the units at their own pace.

(4) Tutors mark assignments and provide assistance to students on an individual basis.

(5) Lectures and demonstrations are used occasionally for enrichment and stimulation.

(6) Progression from one unit to the next is on the basis of mastery as demonstrated by satisfactory performance in some form of test. If students fail to achieve mastery at the first attempt they receive assistance with their problems and may take further tests until they pass.

(7) Final assessment in the course is based on the number of units mastered and/or a final examination. The percentage of marks obtained in unit tests is used only in assessing mastery and not in calculating the final grade in the course.

(8) Student proctors are used to assist in the assessment of student assignments. Keller advocated using advanced students to assist other students and to reduce the amount of routine marking required of staff. In practice this feature of the scheme is rarely workable and most adaptations of the scheme have omitted it.

This scheme has now been used in many tertiary educational institutions over the past decade and considerable experience of its operation is now available. (Green 1971, Taveggia 1976, Friedman *et al* 1976). At Murdoch University various versions of this scheme have been used in the Physics Programme since 1975 (Cornish *et al* 1977). This article is an attempt to assess the value of the scheme and the modifications and further developments which have been found necessary to improve its effectiveness.

Successes of the Keller Scheme

In our experience using various versions of the Keller scheme in several courses in the Physics Programme at Murdoch, we have discovered a number of highly desirable and effective features which are not shared by any of the more conventional methods of course organization. These are :

(a) self-pacing permits students with a wide variety of backgrounds to study the same material because it allows poorly prepared students to spend more time on those sections they find difficult.

(b) students with difficulties can receive individual assistance which is a more effective use of class time than instructor-centred presentations.

(c) students gradually develop self-reliance and learn how to use the library and reference works effectively and how to conduct experiments independently.

(d) if a room can be set aside as a learning centre for a Keller scheme course then students may attend at any time to study, discuss problems with other students and perform experiments. This helps to spread the load on laboratory equipment and permits the integration of the theoretical and experimental aspects of the course. The separation of these two aspects is a common source of criticism in science courses.

(e) failure rates in Keller scheme courses are lower than in conventional courses because weak and poorly prepared students can be identified early and can be given special assistance.

(f) talented students have the opportunity to cover more material than could be expected of the average student by providing additional units for higher grades.

(g) this type of course organization is very effective for external presentation (Cornish *et al* 1981, Jennings *et al* 1982) as off-campus students need explicit statements of course objectives and assessment procedures and detailed instructions on required readings and assignments. Internal study guides can be easily adapted to external use with kits of apparatus being used for the experimental work. Self-pacing is also a suitable feature for external courses because domestic circumstances and postal delays make frequent deadlines unworkable.

In our evaluation of Keller scheme courses in physics we have found a high degree of student satisfaction. Mature-age students especially welcome the opportunity to study at their own pace and take time to overcome the conceptual difficulties they often experience at the start of a new course. Individual assistance is also valued by most students as is the opportunity to integrate their theoretical and experimental work. The availability of a learning centre for the course, where resources and assistance are available, was rated highly by the students.

Problems of the Keller Scheme

There is a considerable body of literature now available on the evaluation of the Keller scheme and various modifications and adaptations of it (Boud *et al* 1975). We found that the unit tests were unworkable because they involved so much routine marking. So we opted for cumulative tests after each block of three or four units. The student proctor scheme also proved unworkable as students are too busy these days to devote large portions of their time to doing what they regard as the staff's work. Many other people have found similar problems with these features and have also abandoned them without fundamentally altering the nature of the scheme (Green 1971).

Some of the more fundamental criticisms of the Keller scheme however strike at its key features of self-pacing, mastery and individualized instruction. The most common criticisms are :

(a) procrastination by students who are not accustomed to self-paced learning and have been trained to work to specific deadlines. This is predominantly a problem for younger, school-leaver students who have been used to teacher-centred instruction in high schools. Mature-age students generally have more experience in organizing their time and workload effectively. Procrastination can be overcome to some extent by urging students to work more regularly on the course and by preparing progress charts showing the current and desirable number of units completed by each student. This is a fundamental problem however with self-pacing and any attempt to solve it appears to lead to an undermining of this feature. Thus the value of self-pacing to the scheme must be evaluated if improvements in the effectiveness of a course are necessary.

(b) some consequences of procrastination are an overload on resources and last-minute cramming and even cheating on assignments in the final weeks of the course. Often these problems arise because students believe that they will be marked harder if they complete a unit first, so they tend to delay and devote their time to other courses and finally seek assistance from the leaders after they have completed a unit. This is not a problem in external courses because students work individually but it can lead to course-wide procrastination in internal courses.

(c) The blend of Keller scheme and continuous assessment courses also produces irregular study patterns and students tend to drop their studies in self-paced courses whenever deadlines and tests occur in other courses. In the Murdoch context it is not uncommon for a student to have three courses running on continuous assessment together with a Keller scheme course. This can mean that students who are struggling in one or more of the other courses work very irregularly in the Keller scheme course and attempt to complete it in a series of short bursts. This often leads to unreasonable demands on staff and resources and complaints from the students about their perceived difficulties with the course.

(d) the amount of staff time required to mount Keller scheme courses. Much time is consumed in routine marking of tests and assignments. Individualized instruction can also be demanding and frustrating especially with very weak students. Mastery is often beyond some diligent but weak students. This often leads to staff objections and a call for a return to traditional course organization where such individual problems can be ignored.

(e) often a successful Keller scheme course will fail when it is handed on to another member of staff with less sympathy or understanding of the method (eg. Friedman *et al* 1976).

Evaluation of the Keller Scheme

It is now clear that the Keller scheme has some fundamental weaknesses which in some circumstances can also be its strengths. The personality and commitment of the instructor is often vital to the success or failure of the scheme. When it is successful it can produce outstanding results in terms of low failure rates, student satisfaction and self-reliance (Taveggia 1976). This is directly attributable to the insistence on clear objectives, detailed study guides, self-pacing and individual assistance to students. Other features such as the integration of theory and experiment and the provision of a learning centre or "home" for the course are supportive but not fundamental to the scheme.

The most apparent problems are those of procrastination and the excessive demands at certain times which it places on staff and resources. These two problems have been traced directly back to the self-pacing and personalized instruction features of the scheme.

Thus it appears that two of the major features of the scheme can be both strengths and weaknesses depending on the circumstances under which the method is used. The logical conclusion to draw from this is that both of these features must be carefully modified to fit the context in which the course is presented. As discussed previously, both features are essential for off-campus learning and they present few problems there. However for internal students working in an environment dominated by continuous assessment it is often necessary to introduce additional deadlines into the Keller scheme courses to prevent excessive procrastination. Also, where classes are predominantly composed of school leavers, it is desirable to provide some optional forms of forced pacing to assist those who are unable to programme their time effectively. Thus the Keller scheme is not a general approach to tertiary teaching but a model on which successful courses can be built in the appropriate circumstances.

The Way Ahead

After nine years' experience with the Keller scheme at Murdoch University it is clear that the procrastination problem is a fundamental flaw which can only be removed by reducing the freedom of pacing in the scheme. However most of the other Keller scheme features have been evaluated and found to be effective. The following features are retained in most modifications of the Keller scheme :

(a) detailed study guides containing specific learning objectives, references, assignments and details of assessment procedures.

(b) modular structure with the course subdivided into weekly units.

(c) subdivision of the class into small groups with each group receiving personalized assistance from its tutor.

(d) occasional large group lectures and demonstrations for information and stimulation.

(e) use of a learning centre where resources and equipment are available for the course and where experiments may be conducted.

In an environment where continuous assessment is prevalent it is often necessary to introduce periodic deadlines into a Keller scheme course. This means scheduling the tests at regular intervals but allowing students to work at their own pace between these intervals. An alternative is to set deadlines for the submission of units. These modifications are often linked to the assessment procedures and marks may be deducted for late submissions of assignments. Alternatively, marks can be allocated only to tests and students may be permitted to resit a test to improve their score and to encourage mastery of the material. The mastery concept is however difficult to maintain in the original sense when any degree of forced pacing is introduced and it could be argued that regular study and periodic assessment are more conducive to long-term mastery than the cramming which results from procrastination.

Some features of any course can be entirely self-paced and this helps to encourage research skills and self-reliance. Project work such as essays or an experimental or computing project can be an important part of a course and students can be given the entire semester to prepare these. However it is still essential to provide clear guidelines for the preparation and assessment of these projects and some deadlines for abstracts and project plans are desirable.

In conclusion the Keller scheme has proved to be highly effective in tertiary physics education. However it must be modified to suit the particular context in which the course is offered. There is no general version of the scheme which is effective in all situations.

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JOHN FORREST NATIONAL PARK AS AN ECOLOGICAL STUDY AREA

Foulds Bill and Parsons Judy

John Forrest National Park is an 'A' class reserve, (M21), largely in a natural state except where access roads and facilities have necessitated some bushland clearing. It is located on the crest of the Darling Range escarpment 26km east of Perth. The Park is the first W.A. National Park (created 1900) though it was originally known as Greenmount National Park but changed to its present name in 1928. It covers an area of c. 1,577 hectares with several steep gradient hills and ridges composed of predominantly lateritic soils. There are granite outcrops and well defined dolerite dykes which run east to west across the park.

Associated with these three distinct geological areas are clearly defined differences in tree, shrub and herbaceous vegetation as well as soil nutrients, colour, texture.

The soils derived from the three rock systems have similar pH values, carbon, nitrogen (nitrate and ammonium), salt (chloride) copper and zinc content (Table 1). However, though the shallow granite and laterite soils are similar the dolerite soil has a much greater manganese, iron and particularly potassium content. This is thought to be due to the higher retention and base exchange capacity of the felspar minerals present in the dolerite rock and therefore soil.

TABLE 1 Soil carbon, pH and nutrient content (ug g^{-1})

	Laterite	Granite	Dolerite
pH	6.1	5.9	6.3
Carbon	1.7	1.6	2.4
Phosphorus	3.4	4.8	5.4
Potassium	48.8	87.0	285.7
Nitrate-nitrogen	2.8	2.7	5.7
Ammonium-nitrogen	2.9	10.0	7.4
Iron	565.0	410.0	1648.0
Chloride	93.0	112.0	112.0
Copper	0.3	0.6	2.8
Zinc	0.7	0.6	0.8
Manganese	9.2	7.1	41.0

The existing National Park carries open-forest and woodland of Jarrah and Marri (System 6). All the areas surveyed are within easy access of the road (Figure 1). The laterite areas are the most densely wooded being dominated by Jarrah and Sheoak with some Marri, Banksia and Wandoo (Table 2). Wandoo predominates in doleritic soil with a few small Jarrah and Marri . The soils around the granite outcrops have a tree stratum similar to the laterite but are lacking in the Banksia and Sheoak species.

TABLE 2 Trees (diameter 4 cm) per hectare

Species	Laterite	Granite	Dolerite
Eucalyptus marginata (Jarrah)	377.7	261.0	33.5
Eucalyptus calophylla (Marri)	62.7	78.0	22.5
Eucalyptus redunca (Wandoo)	40.7	0.0	272.0
Banksia grandis (Bull Banksia)	29.6	0.0	0.0
Casuarina fraserana (Fraser's Casuarina)	248.1	0.0	0.0
TOTAL	758.8	339.0	328.0

The ground flora also shows distinctive distribution (Table 3). The laterite is the richest and most homogeneous area (80 shrub and 35 herbaceous species) while the granite outcrop and fringe area display the least variety of species and are also very heterogeneous consisting of a mosaic of ecosystems each dominated by different plant species.

TABLE 3 Species number, type and distribution

	Laterite	Granite	Dolerite	Total Park
Trees	4	2	2	4
Shrubs	80	20	33	104
Herbs	35	6	18	51
TOTAL	119	28	53	159

Most common families represented

Leguminosae	31	species
Proteaceae	29	species
Myrtaceae	14	species

Although there are 159 plant species so far identified in the areas surveyed the Darling Scarp flora is generally poorly represented in the Park. The number of species in flower throughout the year (Figure 2) differs widely. At the end of the summer drought (April) only seven plants are in flower but after the winter rains (September) as many as 97 can be seen in flower. There is some dieback but only four established alien species were found, which suggests the Park is still in a relatively natural state. Further studies on the fauna should show whether or not the distribution and frequency of the animals is associated with that of the plants.

A complete account of the survey is to submitted to the Western Australian Herbarium Research Notes in 1984.

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REFERENCE

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FIGURE 1 John Forrest National Park (after system 6) L = Laterite

D = Dolerite, G = Granite

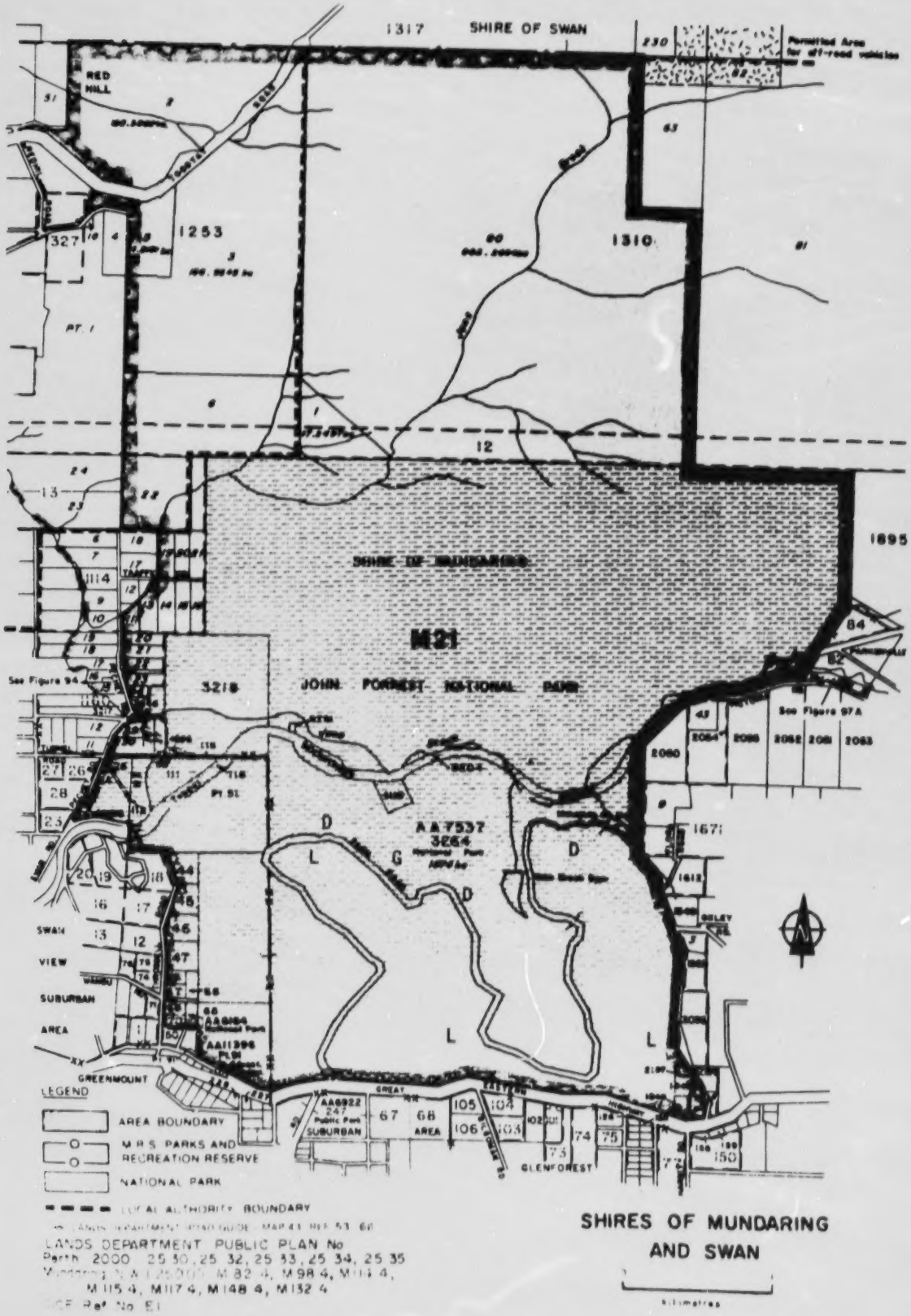
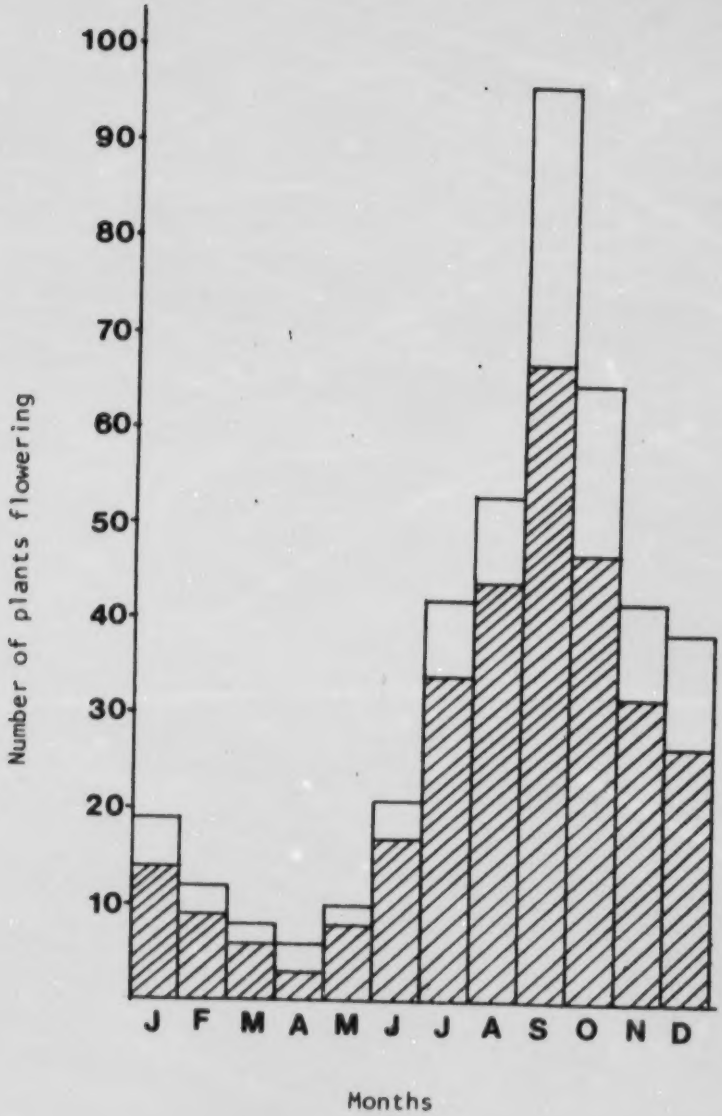


FIGURE 2 Number of woody and Herbaceous plants in flower each month (Hatched = woody species, Open = herbaceous species).



PRIORITIES FOR COMPUTER EDUCATION IN W.A.

Michael J. O'Loughlin and Joseph Luca
Science and Mathematics Education Centre
Western Australian Institute of Technology
Bentley W.A. 6102

INTRODUCTION

There seems little doubt that education systems world wide are making concerted efforts to introduce computers into all levels of formal education. In many countries, governments are allocating significant levels of human and financial resources to computer education. In Australia, State governments, through their respective Education Departments, have promoted the introduction of computers in schools by allocating resources to support services such as teacher inservice, and computing centres.

The allocation of support to these various areas, in government schools at least, is largely determined by the policy of the individual Departments of Education in regard to the priorities for computer education in that State. In W.A., perhaps, the most visible support for computer education in Government schools is the provision of dollar for dollar subsidies for the purchase of approved computer hardware (Penter, 1981). In addition considerable support has been provided for teacher inservice and software development and dissemination. To date, little support has been provided by governments for computer education in independent schools.

Recently, there have been indications that increased resources will be made available for computer education from the Federal government. However, as with all areas of education, the resources that can be allocated to computer education are limited. It is important therefore that these resources be directed toward areas of greatest need. This paper describes a study which was conducted with the specific aim of identifying the level and nature of priorities for allocation of resources for computer education in W.A. schools.

THE RESEARCH METHODOLOGY

THE DELPHI TECHNIQUE

A traditional method used to identify priorities for the allocation of resources within an organization or system is to conduct a round table discussion with a number of knowledgeable individuals from a variety of backgrounds. Through this process either a concensus emerges or a majority view is identified. It is well known that there are serious problems

associated with this approach (Cyphert Grant, 1970; Lonsdale, 1974; Uhl, 1971). Most of these are related to group domination by individuals. For example, group opinion is highly influenced by dominant individuals who usually do most of the talking. Much discussion in group situations, while appearing to be problem orientated, is irrelevant or often biased because it is usually more concerned with individual and group interests rather than associated with a specific problem. Further group pressure to conform can distract individual judgement.

An alternative approach to obtaining consensus that has been widely used in recent years is the Delphi Technique. This approach was originally developed by Rand Corporation as a means to obtain a greater consensus among experts about urgent defence problems without face-to-face discussion (Uhl, 1971). The objective of the Delphi Technique is to obtain the best consensus of opinion from a group of experts through a series of intensive questionnaires, alternated with controlled feedback of opinion. The rationale of the techniques is based upon the use of experts, the anonymity of the respondents, the interaction and controlled feedback of the opinions of respondents and the use of statistics to aggregate the opinions.

Essentially, the Delphi technique consists of a panel of experts who are asked to indicate their opinions on one or more problems in terms of given criteria. The replies of all respondents are analysed in order to obtain, for each "item", a measure of the overall group opinion together with a measure of the range of opinion. In the light of this information respondents reconsider their opinions and provide written justification for those in a second questionnaire. The process is repeated two or more times and on each occasion respondents are provided with feedback from the other members of the group.

This study utilized a modified Delphi Technique involving a series of three questionnaires. The nature of these questionnaires is explained in a following section.

THE SAMPLE

The participants selected for this study comprised of: a) educational administrators from the Education Department of W.A. and secondary schools b) computer educators from tertiary institutions c) specialist computer education personnel from the Education Department and d) secondary school computer educators. The sample is described in Figure 1.

PARTICIPANTS	N SIZE
Educational Administrators	11
Tertiary Computer Educators	11
Special Computer Education Personnel	4
Secondary Computer Educators	17
Total	43

Figure 1: The study sample

THE PROCEDURE

The Delphi Technique as used in this study utilised three questionnaires. The first questionnaire asked the participants to list those areas in computer education that they considered should receive high priority in the allocation of resources in computer education. This was achieved by asking the participants to respond to the following statement using the prompts provided :

> In the next few years, those persons involved in computer education in W.A. secondary schools should concentrate their energies and resources toward:
>
> INCREASING _____
>
> PREPARING _____
>
> DEVELOPING _____
>
> SOLVING _____
>
> ( ) _____

The responses to this question were then collated and for ease of questionnaire construction were placed in seven categories based on the general nature of the responses. The categories were as follows:

- Computer Education Curricula and Resources
- Computers in School Curriculum
- Teaching Computer Education
- Teacher Training
- Hardware
- Software
- Administration of Computer Education.

Almost 140 responses were recorded under these seven categories. These individual statements were reduced to 42 generic statements that encompassed related ideas. These 42 statements were then used as the basis for the second questionnaire.

In questionnaire 2, each of the 42 statements were listed and the participants were requested to assign a level of priority for the allocation of resources - on a five point scale from Highest priority to Lowest priority - for the activity or are a indicated in each statement.

For the third round of the Delphi Technique the items were resorted on the basis of the average level of priority assigned to each item on the second questionnaire and the general area to which they related . From this process, seven categories ranked in order of priority were identified. Questionnaire 3 was constructed from the 42 items resorted into these seven new categories.

Questionnaire 3 listed separately the items in each of the seven categories listed beside each item was a breakdown of the priority ratings of the group of participants for that item. The modal rating for each item was circled to allow participants to easily compare the relative ratings of items. In addition, individual questionnaires were prepared for each participant which indicated that participants rating of each item from the previous round. Each participant was given the opportunity of revising that rating. At the end of each category a short summary of the main points in that category was given.

In responding to Questionnaire 3 each participant was asked to:

a) indicate their level of agreement to the priority allocated to each category by the group on a five point Likert scale (strongly agree - strongly disagree) and;

b) to provide reasons for their agreement or disagreement with that priority.

RESULTS AND DISCUSSION

Figure Two lists the seven categories of statements in order of priority and the statement summarizing the contents of the items in each category. In addition, The Figure One shows the level of priority assigned to that category by the participants and the level of agreement of the participants with that priority.

Figure Three shows the items included in each of the seven categories with the breakdown of the priority ratings allocated by the participants. The modal rating is circled. In addition a summary of the reasons supporting and not supporting the allocated priority for that category are included with each category. These results are now discussed under categories of priority.

AREAS OF HIGH PRIORITY

The integration of computers and computer education across all areas of the school curriculum was strongly supported by the participants. The following comment reflects most of the ideas which were given in support for this area:

> Until all subject areas become involved in computer education, the full impact of computers in Society cannot be fully illustrated to students.

However, while agreeing with the allocation of high priority to this area, some participants believed it necessary to first have extensive curriculum materials developed before making a major effort to integrate the use of computers in all areas of the school curriculum.

A second area identified as high priority was the need to develop courses which would prepare all students to enter a computer orientated society. Many participants indicated that any students that were not familiar with computers, their uses and limitations would be at a considerable disadvantage upon entering the workforce. Only one participant strongly disagreed with this viewpoint by highlighting the point that whether a student would be prepared for a computer orientated society or otherwise, would depend on that student's intelligence, enthusiasm, or soci-economic background. Further, the best way for preparing students would be to provide information and knowledge which would allow students to pursue specific areas or topics in computing of interest to them.

It is interesting to compare similarities of the high priority areas just discussed, with the policy of the Education Department (Education Department of Western Australia, 1981). The three main components of the Education Department's computer education programme in Years 8-10 are:

- The utilization of the computer, within a range of subjects, to enhance the teaching of those subjects.
- The study, probably within a social studies programme, of the impact of information technology or society.
- The involvement of students in a short sequence of simple programming experiences.

The Education Department policy for priorities in computer education in Western Australian secondary schools is very similar to the two high priority areas developed through the Delphi survey.

One specific item of interest in the high priority category is the demand for a T.A.E. course. It was proposed that such a course would give computing respectability and status. However a number of respondents were concerned that such a course would attract good students and teachers away from the traditionally more difficult mathematics and science subjects.

AREAS OF HIGH-MEDIUM PRIORITY

Three targets which were given a high-medium level of priority were entitled: "Software", "Computing Facilities", and "Teachers of Computer Education". These three areas are mainly related to developing the use of computers in classrooms for assisting teachers to carry out labour intensive tasks, so that they may have more time for lesson preparation and presentation.

Many respondents were of the opinion that more relevant software and large numbers of microcomputers were needed in the schools to assist teachers. If software relevant to W.A. schools was widely available and there was sufficient software to make assisted learning viable, then there may be less resistance among teachers for using the new technology. The need for more hardware to provide a "hands-on" approach to computer awareness courses proved to be a very high priority. However, some participants saw no need for more hardware in schools; they considered that more hardware could be easily abused and create bad programming habits and misuse of computers. On the other hand the point could be made that some students already have home computers and would pick up these habits with or without formal "instruction".

AREAS OF MEDIUM PRIORITY

Many participants indicated a need to resolve differences in opinion on policy matters between teachers and computer education administrators. There seems to be a wide range of opinion about the implementation of the Education Department computer education policy in schools. Many computer education teachers wanted a convenient means of discussing policy with those making the rules. A number of participants indicated that they considered there was a lack of communication between computer education teachers and specialist computer education staff from the Education Department. The view was expressed that current policies were too restrictive on teachers and were not supported by some computing teachers. The questions were raised: "who knows what is best for the State in computer education?"; "Should all teachers be forced to adopt the same policy in such a new and quickly expanding field?"

AREAS OF LOW PRIORITY

Most participants were of the opinion that developing student programing skills was of low priority and should be left to the tertiary institutions. The view was put forward that schools should mainly concentrate on developing computer literacy of which programing was only a small part. However, there was a group of participants who strongly disagreed with this view. They believe that computer education will never have status or respectability until programing is a true part of the computer education course; and, parents and the public in general want and expect students to learn programing skills in the schools.

CONCLUSIONS

The results of the study show that there is a high degree of consensus among computer educators and educational administrators that the highest priority for the allocation of resources in computer education is to promote the use of computers by teachers from all subject areas through inservice courses, the provision of suitable courseware and the like. High priority was also given to the development of a range of computer education curriculum materials. These materials ranged from a TAE computer education course to teaching notes and assessment procedures for teachers.

Three major areas were identified at the next level of priority. The first of these was related to the provision of a large range of high quality educational software to schools. Associated with this area was the provision of increased computing facilities in schools, in particular microcomputers with networking and graphics capabilities. High medium priority was also given to the allocation of resources to increasing the number of teachers with formal qualifications in computer education and to

the provision of promotional positions in computer education. Low priority was allocated to the teaching of programing to secondary students.

The priorities identified in this study are in close accord with the priorities for the use of computers in secondary schools as described in the Education Department policy statement (Education Department of Western Australia 1980, Hoffman, 1981); that is the provision of computer awareness programmes for all students and in the teaching-learning programmes of the various subject areas.

The development of computer education curricula for secondary schools was an area identified as having high priority. While there is some effort being given to the development of new syllabi for lower school computer awareness and infomation courses and T.A.E. computer studies course, it is the authors' contention that increased resources should be allocated to the development of a range of teacher and student oriented teaching and learning materials. It is, perhaps, unrealistic to expect much school based curriculum development given that computer education is in its infancy compared to other subject areas and that there are few experienced and well qualified teachers in the field.

It is apparent that since the study was conducted (mid 1982) there have been developments which have addressed a number of the aspects raised. In particular the increasing acquisition of microcomputers by schools is alleviating the problem of insufficient computing facilites. The use of microcomputers is also increasing the range of educational software available for use in schools and has increased the opportunities for computer assisted learning in all subject areas.

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Category	Allocated Priority	Level of Consenus*
1. Computers Across the Curriculum		
For the allocation of resources to be given to the intergration of computers and computer education across all areas of the school curriculum	High	92%
2. Computer Education Curriculum		
For the allocation of resources to be given to developing computer education curricular for years 8-10 and years 11-12 which include teaching notes, suggested teaching strategies and more specific assessment procedures.	High	94%
3. Software		
For increasing the quality and range of educational software, including user documentation which is more open-ended and user disected.	High-Medium	85%
4. Computing Facilities		
For increasing computer facilites in schools, in particular microcomputers and microcomputers networks, with increased capabilities.	High-Medium	89%
5. Teachers of Computer Education		
Resources should be allocated to increasing the number of teachers with formal qualifications in computer education and to developing promitional positions in computer education. Resources should also be allocated toward increasing the time available to there teachers to examine courses.	High-Medium	74%
6. Administration of Computer Education		
For establishing consensus between computer education administrators and teachers on computer education policy matters and develop and promote communication channels between computer educators/schools.	Medium	80%
7. Importance of Programing	Low	75%
For the allocation of resources to be given to the teaching of programming skills to students.		

Figure 2: Areas of Priority of Computer Education

* % of participants agreeing or strongly agreeing with allocated level of priority for each category.

HIGH PRIORITY

COMPUTERS ACROSS THE CURRICULUM

ITEMS	HIGHEST PRIORITY	ABOVE AVERAGE PRIORITY	AVERAGE PRIORITY	BELOW AVERAGE PRIORITY	LOWEST PRIORITY
1. Solving the problem of how to integrate the use of computers into the teaching programmes of each subject area.	(19)	9	8	4	1
2. Developing in teachers, the ability and motivation to include the use of computers in their courses.	(20)	12	6	2	1
3. Developing inservice courses for classroom teachers of all disciplines of computer awareness, operations and uses.	(19)	14	7	1	-
4. Increasing the involvement of computer education teachers in areas other than maths and physical science.	9	(20)	7	2	3
5. Developing curriculum material involving computer use across all subject areas.	12	(18)	4	5	2
6. Increasing the use of computers in remedial and special education.	5	12	(18)	4	2

REASONS SUPPORTING ALLOCATION OF HIGH PRIORITY

The best way to give children appreciation of the computer is by using it across the curriculum

By increasing the use of computers in other subject areas, the problem of computers being associated only with mathematics will be reduced.

Computers are entering the workforce at an alarming rate. In order to be prepared, we must ensure that all students and teachers can interact with and utilize the facilities of a computer.

Intergration of computers across the curriculum will help break down the mistique computers have in the minds of many teachers.

Computers touch all aspects in our lives today. This should be reflected in the schools.

Until all subject areas become involved in computer education, the full impact of computers in society cannot be fully illustrated to students.

REASONS NOT SUPPORTING ALLOCATION OF HIGH PRIORITY

It is unnecessary to have curriculum materials developed before making a major push with teachers across the curriculum.

Integration of computer education across the curriculum should follow the development of a computer course in year 11/12, otherwise the computer courses developed for Years 9 - 12 will always be substandard.

Teacher priority should be given to developing more software rather than running inservice courses.

COMPUTER EDUCATION CURRICULA

ITEMS	HIGHEST PRIORITY	ABOVE AVERAGE PRIORITY	AVERAGE PRIORITY	BELOW AVERAGE PRIORITY	LOWEST PRIORITY
1. Developing resources for a computer awareness course aimed at years 8-11.	16	(16)	9	2	1
2. Developing courseware specifically suited to W.A. schools curricula.	(19)	12	11	2	1
3. Preparing students for a computer oriented society and workforce.	(20)	10	10	1	-
4. Developing a TAE course for computer education.	12	(15)	6	7	1
5. Preparing teaching notes and strategies for use by classroom teachers.	6	(22)	11	2	-
6. Preparing more highly structured curriculum materials for computer education courses.	2	12	(20)	5	2
7. Developing more specific assessment procedures for computer education courses.	4	(17)	17	3	-
8. Increasing business orientation of computing courses.	2	9	(15)	13	2
9. Developing more effective teaching strategies to overcome minimal equipment/maximum student class size in computer studies.	8	(19)	7	3	4
10. Increasing the range of computer education courses available to cater for different student abilities and interests.	4	11	(15)	8	1

REASONS SUPPORTING ALLOCATION OF HIGH PRIORITY

Well prepared courseware should bridge the knowledge gap for the willing but inexperienced teacher of computing.

Most teachers need expert help to pass on necessary information to students. The changes in computing are too rapid for individual teachers to keep up with.

Students unfamiliar with computers, their uses and limitations will be at a considerable disadvantage upon entering the workforce.

A T.A.E. course in computing will give computing/computer studies a greater responsibility, higher status, recognition by teachers, students, parents and public than at present.

That there is already plenty of resources available for developing computer education. It only needs collecting and organizing by a central body.

REASONS NOT SUPPORTING ALLOCATION OF HIGH PRIORITY

That computing is an area of constant change. Unless the teacher is in the position to be able to review these changes himself, he cannot expect the body to properly achieve this for him.

Teachers are not the ones [illegible] students for the workforce. They should be trying to give them the background knowledge that will allow them to develop their own areas of interest.

HIGH SCHOOL PRIORITY

SOFTWARE

ITEMS		HIGHEST PRIORITY	ABOVE AVERAGE PRIORITY	AVERAGE PRIORITY	BELOW AVERAGE PRIORITY	LOWEST PRIORITY
1.	Increasing the quality and range of education software, including user documentation.	(24)	8	5	3	1
2.	Developing and disseminating of more 'open-ended' (i.e. non-prescriptive, versatile, user directed) software.	9	(16)	12	3	1
3.	Developing a mechanism to distribute and collect software developed in schools.	10	8	(18)	3	2
4.	Increasing suitable software packages for school administration use (records etc).	4	8	(15)	6	8

SUMMARY

REASONS SUPPORTING ALLOCATION OF HIGH PRIORITY

The only way to integrate computers across the curriculum thus giving computer awareness to students, is to have good software available which teachers from a range of disciplines will find valuable to use.

Programs should be developed to assist teachers to carry out labour intensive administrative tasks, so that they have more time for less preparation and presentation. This is the case in other industry, why not education?

Administration use of computers will help acceptance and support.

Teachers are more likely to use material if they can easily adapt it to their own needs.

Without good software computers are junk.

Schools need software designed for W.A., rather than software designed for Britain, U.S.A., etc.

REASONS NOT SUPPORTING ALLOCATION OF HIGH PRIORITY

Until sufficient hardware is available the software problem is a non-event. Once hardware is available in large numbers, then software is a high priority.

Improving knowledge of what is available and how to use it is more important than generating further software.

A wealth of material already exists and can be obtained from commercial sources.

The return for the expenditure involved in using the computer for administrative tasks is of questionable educational value to the students.

Computers should not be important to administrative functions. Experience has shown that offices within the school or inside the department if the administration want [illegible] to have access to the same results.

[illegible] programming and programming in general [illegible]

COMPUTING FACILITIES

ITEMS		HIGHEST PRIORITY	ABOVE AVERAGE PRIORITY	AVERAGE PRIORITY	BELOW AVERAGE PRIORITY	LOWEST PRIORITY
1.	Increasing the number of microcomputers in schools.	(17)	16	4	3	1
2.	Increasing the capabilities of hardware to cater for applications such as graphics, data bases etc.	10	(14)	8	4	4
3.	Developing networking of microcomputers in schools.	7	(11)	10	6	4
4.	Increasing 'hands on' computer experience for each student.	8	13	(17)	3	-
5.	Increasing the number of 'on line' terminals in schools.	4	6	(13)	12	6
6.	Increasing the standardization in hardware	10	8	(14)	8	1
7.	Developing the use of satellite technology for isolated schools/students.	2	9	(13)	8	9
8.	Providing equal support for all W.A. government high schools i.e. metro, country, senior and district.	5	13	(17)	4	2

REASONS SUPPORTING ALLOCATION OFHIGH PRIORITY

Before computers can achieve anything like a realistic impact upon a school, general student access to computers will have to be dramatically increased.

Easy access to computing facilities for teachers in all departments is essential if computers are to be integrated into a range of subject areas.

Many homes have computers and most jobs will involve some computer usage.

Without "hands-on" approach, computing courses will lack relevance.

There is a high motivation value in producing a "hands-on" approach for students.

REASONS NOT SUPPORTING ALLOCATION OF HIGH PRIORITY

Other areas such as staff resources and software should be of higher priority, in order that the existing facilities are used more effectively.

At present many schools are protected from the worst excesses of inappropriate use of facilities by their scarcity. [illegible] would feel more comfortable if the call for further facilities followed a recognition of the available use of the same. Why are more microcomputers needed?

Computing facilities in the absence of good software/trained teachers are of little use.

HIGH MEDIUM PRIORITY

TEACHERS OF COMPUTER EDUCATION

ITEMS		HIGHEST PRIORITY	ABOVE AVERAGE PRIORITY	AVERAGE PRIORITY	BELOW AVERAGE PRIORITY	LOWEST PRIORITY
1.	Increasing the number of teachers with formal qualifications in computer education.	8	(17)	14	2	-
2.	Developing promotional positions in all schools for Senior Master/Co-ordinator of computer education.	10	(14)	10	6	1
3.	Increasing the time available to the teachers organising computer education courses.	12	8	(15)	6	-
4.	Organising inservice courses for teachers to develop software.	7	8	(12)	8	6

REASONS SUPPORTING ALLOCATION OF HIGH PRIORITY

The only way progress will be made in computer education is to give incentive to those in charge. (Qualifications or no qualifications.)

A coordinator of computer education is needed in each school who has the knowledge, resources and time to serve the needs of the whole school. This needs to be a promotion position to put the coordinator at the correct staff level to converse equally with the other senior personnel. Until this is done, computer studies will always be ad-hoc, unprofessional, and disjointed.

A large number of experienced people will soon be required to cope with rapidly increasing demand in this area.

If the software is to be relevant for education, then it should be written by people practising education.

Inservice courses are one way of successfully producing software in a reasonable manner at a realistic cost.

REASONS NOT SUPPORTING ALLOCATION OF HIGH PRIORITY

Currently no computer education teachers are appointed to schools. Until this situation changes, there is no need to develop promotion positions.

I do not want a senior master of computing. It would make computing an island, i.e. other disciplines would consider it his job, not mine.

The problem is to convince ALL teachers to use computers in their course. Formal qualifications for some will not help. Most inservice for ALL teachers should aim at using not programming.

MEDIUM PRIORITY

ADMINISTRATORS OF COMPUTER EDUCATION

ITEMS		HIGHEST PRIORITY	ABOVE AVERAGE PRIORITY	AVERAGE PRIORITY	BELOW AVERAGE PRIORITY	LOWEST PRIORITY
1.	Resolving the differences of opinion that exists between computer education administrators and teachers on policy matters related to computer education.	11	(11)	9	2	7
2.	Increasing the involvement of teachers in decision making.	5	11	(19)	5	1
3.	Reducing divisions between teachers on what should be done with computers in schools.	-	13	(14)	8	5
4.	Appointing the most experienced and qualified people to administer computer education from either within or outside the Education Department.	10	10	(15)	5	1
5.	Developing increased awareness of the importance of computer education among high level educational administrators.	7	16	(17)	1	-
6.	Developing better communication channels among computer educators/schools i.e. software interchange system and newsletters.	9	(15)	12	4	1

REASONS SUPPORTING ALLOCATION OF HIGH PRIORITY

If computer education is to succeed it must have strong leadership and good communication channels.

The differences between teachers and administrators must be resolved if computer education is to advance.

Variation if computer education policy between schools is not necessarily a disadvantage, provided adequate communication channels exist betwen all those involved in computer education.

REASONS NOT SUPPORTING ALLOCATION OF HIGH PRIORITY

Fails to see the need to involve teachers in decision making.

There are other areas which are most important that this and needs attention before we look at this one.

If unreasonable or inadequate expectations are made by administrators, teachers have a way of implementing their own thing.

LOW PRIORITY

IMPORTANCE OF PROGRAMMING

ITEMS	HIGHEST PRIORITY	ABOVE AVERAGE PRIORITY	AVERAGE PRIORITY	BELOW AVERAGE PRIORITY	LOWEST PRIORITY
1. Providing higher level courses in computer programming	3	2	8	(21)	1
2. Preparing teachers to teach programming.	2	0	(16)	15	2
3. Increasing the proportion of students who learn programming skills.	-	2	10	(19)	10
4. Increasing involvement of students in writing programmes suitable for use by classroom teachers.	-	3	9	10	(19)

151.

REASONS SUPPORTING ALLOCATION OF HIGH PRIORITY

Programming skills should be left to tertiary institutions, where the wide range of problem-solving and analysis can also be developed. Schools should concentrate on giving as broad an education as possible.

The main aim should be to develop computer literacy among large populations.

Programming will become an increasingly low priority as software increases.

There are few students who have the maturity to handle high level programming!

Teaching programming is only a small part of computer education. Acceptance across all subject areas and by all teachers is much more important.

REASONS NOT SUPPORTING ALLOCATION OF HIGH PRIORITY

There is a keen interest among students to learn programming and considerable support from parents.

By allocating resources for the teaching of programming, schools will be able to build respectable computing departments. Schools without programming as a priority in their computing courses don't really need computers to teach computing.

Students will be better suited to the workforce with programming skills.

Perhaps for the majority of students this is a low priority area, but the more able must be considered and I feel this area needs to have more emphasis.

TECHNIQUES FOR FORMATIVE EVALUATION OF SCIENCE CURRICULA

Barry J Fraser

Western Australian Institute of Technology

In a recent book from the Stanford Evaluation Consortium, Cronbach and colleagues claim that

> Evaluators gain much experience in the course of designing and redesigning a study. Unfortunately, little of that experience is recorded for the benefit of the evaluation community ... Methods of evaluation would improve faster if evaluators more often wrote retrospective accounts ... (Cronbach et al., 1980, p. 214)

Moreover, Anderson and Ball (1978, p. 101) note that what exists in the literature in terms of reports of evaluation efforts almost exclusively focuses on summative evaluation, while reports of formative evaluation efforts are particularly scarce. One reason for this, of course, is that summative evaluation reports serve wider audiences, whereas formative evaluation reports are likely to be of interest predominantly to the curriculum developers themselves. Nevertheless, a portrayal of the formative evaluation procedures which were followed by a specific curriculum project potentially could provide valuable guidance to others embarking on formative evaluation initiatives.

The formative evaluation activities associated with the Australian Science Education Project (ASEP) are among the most comprehensive employed in any Australian curriculum venture. Despite this, information about the nature and effectiveness of ASEP's formative evaluation procedures has remained hitherto an unavailable source of potential insight for other people engaged in formative evaluation. Consequently, in an attempt to enlighten others involved in formative evaluation, this chapter aims to describe, illustrate with concrete examples, and draw implications from the formative evaluation activities associated with ASEP.

NATURE OF PROJECT AND ROLE OF EVALUATION

Between October 1969 and March 1974, ASEP developed materials suitable for the range of science courses and conditions at the junior high school level in all Australian states. ASEP materials published during 1974 included 41 units for student use, each occupying about a month's teaching time, and six service booklets and some audiovisual material for use with student units. For the development of ASEP, the sum of approximately 1.2 million dollars Australian was made available jointly by the commonwealth government and the six state governments. Furthermore, the development of ASEP materials can be considered an important landmark in the history of Australian education because ASEP was its first national curriculum project in any subject area.

Descriptions of the historical beginnings of ASEP and the nature of ASEP's philosophy and materials are provided in detail elsewhere (Lucas, 1972; ASEP, 1974; Fraser 1979a). In order to facilitate understanding of ASEP's formative evaluation activities, a few salient features of ASEP materials are noted here. First, ASEP materials are organised into a large number of relatively independent units so that the teacher has a degree of choice in which ASEP units to use and in what sequence. Second, ASEP materials cater for student individual differences by providing student options within each ASEP unit and by allowing students to proceed through the materials at their own rates. Third, ASEP materials are activity based and engage students in inquiry strategies.

Since ASEP's main charter was the development of materials, the primary goal of evaluation within ASEP was the formative one of guiding the ongoing development, revision and improvement of materials. The summative evaluation of individual or groups of units, therefore, was

considered of relatively minor importance to internal project staff. It is noteworthy, however, that external evaluators or researchers have engaged in a number of interesting summative evaluation efforts in relation to ASEP and that these have formed the basis of a separate comprehensive review (Fraser, 1978a,b).

THE EVALUATORS

The people involved in formative evaluation were internal project staff who were designated as ASEP's "Research Officers". There was a close and cooperative relationship between curriculum developers and the Research Officers responsible for evaluation.

Although there were three or four full-time Research Officers on average throughout the life of ASEP, it is important to appreciate that only part of their time could be devoted to curriculum evaluation initiatives. In particular, the writing of diagnostic tests for inclusion within ASEP units occupied a sizable amount of the Research Officers' time and reduced their capacity to do curriculum evaluation work.

STAGES AT WHICH EVALUATION WAS CONDUCTED

Formative evaluation was conducted at each identifiable stage of ASEP's curriculum development process. Project staff determined the same stages at which all units were evaluated. In particular, prior to field testing, "reflective" or "armchair" evaluation was conducted to provide preliminary information to guide the development and modification of units. This involved a group of ASEP staff in scrutinising each unit's first and second specification, and the presentation and approval of a first trial version and later a second trial version of materials to ASEP's academic and editorial staff. This reflective evaluation was found to

provide a rather economical way of evaluating, eliminating and modifying units at an early stage prior to incurring the expenses of production and field trials.

The major formative evaluation efforts were associated with the field testing of prototypes of ASEP units. The majority of ASEP units underwent field testing twice. The first versions of ASEP units were subjected to local field trials in schools in Victoria, whereas the second versions underwent trials in a national sample of schools. However, there were a number of noteworthy exceptions to this pattern. Firstly, as a few units were essentially adaptations of units developed previously overseas, these were subjected only to the second (national) field trials. Secondly, as time and funds ran out towards the end of the project, it proved necessary to exclude some units from the national trials.

SAMPLES

One major difference between the first and second trials was that the first trials involved a smaller number of classes (about eight) located in the Melbourne metropolitan area in close proximity to the ASEP headquarters, whereas the second trials involved a larger number of classes (over twenty) drawn nationally from all Australian states. An important reason why the first trials were locally based was to enable close contact to be maintained between ASEP staff and trial schools. The restriction in the size and location of the sample for first trials also provided a relatively economical initial tryout of materials. In contrast, the more comprehensive national trials were designed to determine the suitablity of units in a wider variety of classrooms, to ascertian the specific needs of the various states, and to determine sources of equipment and aids for the units in various states.

RANGE OF METHODS OF FORMATIVE EVALUATION

The range of alternative evaluation techniques available for use in formative curriculum evaluation is quite broad (see Grobman, 1968; Baker & Alkin, 1973; Baker, 1974, 1978; Champagne & Klopfer, 1974; Sanders & Cunningham, 1974; Harlen, 1975; Krus et al., 1975; Novick, 1976; Steadman, 1976; Bloom, 1977). It is noteworthy that ASEP's formative evaluation activities also were very broad in scope and encompassed numerous and varied approaches. A major purpose of this section is to provide concrete illustrations of each of the techniques followed by ASEP and record some tentative observations about their usefulness. Although there existed some differences in the evaluation procedures followed in the first and second trials, they were sufficiently similar in many respects to permit them to be treated together in this section.

Experts' Responses to Structured Questionnaire

The collection and collation of expert opinion was a major approach to the evaluation of the trial versions of ASEP units. For each ASEP unit, the same structured questionnaire was completed by a group of experts consisting of external consultants, teachers whose classes were involved in the classroom tryout of the unit, and members of State Advisory Committees (i.e., special groups of science educators and teachers organised by ASEP in each state to assist the Project). In particular, the State Advisory Committees paid special attention to any specific difficulties which were likely to arise in using the unit in their own state (e.g., because of special syllabus requirements).

In the case of the first trial of the unit "Charge", a total of 39 experts provided responses to structured questionnaire items. The first group of experts consisted of four external consultants (mainly from colleges

and universities) who were known for their special interest either in physics or physics education. The second group consisted of the eight teachers of the classes involved in trialling the unit in schools in the metropolitan area of Melbourne. For this particular unit, three of the schools were coeducational government high schools, three were girls' non-Catholic independent schools, one was a Catholic boys' school and one was a non-Catholic independent boys' school. The remaining group comprised 27 members of State Advisory Committees (five from South Australia, seven from Queensland, four from Western Australia, five from Victoria, three from Tasmania and three from New South Wales).

These experts were asked to provide their opinions about the 27 different aspects of the unit shown in Table I by responding on a fivepoint scale ranging from "very favourably impressed" to "unsatisfactory". It can be seen from Table I that the 27 individual items covered four areas, namely, ASEP philosophy, student materials, teachers' guide, and appearance and production. But, as people were allowed to omit a rating for any aspect about which they felt unable to comment, the frequencies of all ratings do not always sum to 39.

As different experts could have different perspectives, clearly the responses of each individual were important. But, at the same time, the total amount of information available tended to be unwieldy since the responses of 39 different experts to 27 different questions produced 1,053 different pieces of information. Also, the time pressures associated with ASEP's production schedule meant that the collation of feedback material and its use in revising units had to be completed within a fairly limited time period. Consequently, these time pressures led to some conflict between the need to pay careful attention to the differences in opinion

TABLE I. Summary of Experts' Responses to Structured Questionnaire Items about the Unit "Charge"

	Aspects of Unit	Frequency of Rating				
		Very favourably impressed				Unsatisfactory
		1	2	3	4	5
1.	ASEP Philosophy					
1.1	Reflection of ASEP Objectives	17	18	1	-	-
1.2	Reflection of ASEP Content Themes	20	13	2	1	-
1.3	Adherence to ways of dealing with subject-matter according to Piagetian theory	11	13	8	1	-
1.4	Provisions for individual difference	16	12	9	1	-
1.5	Use of the enquiry approach	16	15	5	-	-
2.	Student Materials					
2.1	Authenticity of science content	22	11	5	-	1
2.2	Appropriateness for students' levels of development	11	19	6	1	-
2.3	Appropriateness for existing classroom conditions and resources	14	16	9	2	2
2.4	Organization and structure of learning experiences	15	16	6	2	-
2.5	Quality of tests	14	12	10	3	-
2.6	Suitability of students' recorded work	10	15	8	2	2
2.7	The name of the unit	18	8	2	-	-
2.8	The length of the unit	7	14	9	3	1
3.	Teachers' Guide					
3.1	Adequacy of information supplied	9	16	10	-	-
3.2	Adequacy of suggestions for classroom organization and procedures	11	12	6	2	1
3.3	Adequacy of lists of equipment required	17	13	4	2	-
3.4	Adequacy of lists of references and audio-visuals	2	6	12	7	-
3.5	Ease of use	10	16	5	3	1
3.6	Layout and organization	13	20	3	1	2
4.	Appearance & Production					
4.1	Style	11	15	10	1	-
4.2	Layout	5	23	7	3	-
4.3	Grammar and punctuation	5	19	9	1	4
4.4	Typography	8	13	13	-	1
4.5	Size of booklets	20	8	7	3	-
4.6	Photographs	10	19	5	3	2
4.7	Diagrams and illustrations	12	12	7	3	1
4.8	Cartoons	14	13	4	7	-

expressed by each of the 39 experts, and the need to summarise the cumbersome set of data quickly in a manner which highlighted major trends. These considerations led to the practice of aggregating responses across the whole group of respondents as shown in Table 1. Although the curriculum developers had access to each expert's individual responses when rewriting the unit, a certain amount of time was saved by using summaries like that illustrated in Table 1 to identify general trends and specific areas for which the responses of individuals needed to be scrutinised more closely.

Experts' Unstructured Comments

In addition to the structured questionnaire described above, each of the 39 experts also were asked to provide unstructured comments which were recorded either as responses to open-ended questionnaire items or which were recorded directly onto a copy of the unit itself. Also, some of these experts provided a covering letter which made additional global statements about a unit. In order to provide concrete illustration of the types of information obtained by these methods, Table 2 lists some typical examples of comments made by the same group of 39 experts who were involved in evaluating the first trial version of "Charge".

Meetings of Trial Teachers and ASEP Staff

During the first field testing of each ASEP unit, trial teachers visited ASEP headquarters every two weeks to meet with the writers and other ASEP staff. At these meetings, ASEP staff could ask questions and teachers could report their experiences and problems. Teacher emphasised what students and teachers actually were doing in the classroom, and ASEP

TABLE 2. Unstructured Comments Made by Experts about the First Trial Version of "Charge"

External Consultants

This unit is brilliant in concept and execution.

Fine! The unit is experimentally based, interesting and relates to the environment.

The teachers' guide did not measure up.

Much improvement is needed in editing.

Teachers

I am afraid I could not justify the time involved in this unit.

The students became bored.

The unit achieves the goals of ASEP.

Although very enthusiastic at first, students lost interest towards the finish.

I feel the unit tried to cover too much territory.

I think it is an excellent unit and thoroughly enjoyed trialling it. Most of the trial class also enjoyed it and gained a lot from it.

A good unit which measures up well on most points.

When preparation time is taken into account, it would be unrealistic to think that it would be feasible to introduce ASEP into the schools unless laboratory assistance was assured.

State Advisory Committees

I tried the experiments myself and feel they would provide students with a good grasp of the concept of charge.

In general I thought the students' booklet showed a patronizing attitude to the teacher.

The teacher's guide is padded out with fairly useless photographs and diagrams.

The unit as a whole is excellent both in content and approach and provides a good set of graded options.

The standard of editing is incredibly low.

The layout needs improvement.

An excellent unit; the best I have seen to date.

The format of the teachers' guide is piecemeal.

staff provided guidance about what future parts of the unit would involve. Also some audio and video tapes were made of some lessons as a basis for discussion during these meetings. The national trials were not organised in a way which provided the opportunity for meetings between ASEP staff and trial teachers. Nevertheless, because of the value of this type of feedback, ASEP staff supplemented the list of national trial schools with several other local schools which could be visited by ASEP staff.

Trial Students' Responses to Structured Questionnaire Items

The evaluation of trial versions of units was based also on student responses to a short structured questionnaire. Table 3 shows six aspects of each unit which were rated by trial students using a five point scale ranging from "liked very much" to "disliked very much". As there were relatively few items in this part of the questionnaire, it proved feasible to collate results separately for each individual class involved in the first trial. As a greater number of schools was involved in the national trial, results tended to be collated separately for the group of classes in each State. Table 3 presents data from two of the individual schools involved in the field testing of the first version of "Charge". For economy, however, ASEP staff collated information for a random sample of only 15 students from each class instead of using all students. The bottom of Table 3 provides aggregated results for a sample of 105 students consisting of 15 students chosen randomly from the seven schools whose feedback had been received at the time of collation.

Trial Students' Responses to Unstructured Questionnaire Items

In addition to responses to the structured part of the student

TABLE 3. Summary of Student Responses to Structured Questionnaire Items

School	Aspect of Unit	Frequency of Rating				
		Liked very much 1	2	3	4	Disliked very much 5
School A (N=15)	Subject-matter	2	7	3	1	2
	Experiments	6	7	1	1	-
	Tests	-	5	6	1	3
	Photographs	1	7	6	-	1
	Diagrams and illustrations	4	3	3	2	3
	Reading level	1	6	4	2	2
School B (N=15)	Subject-matter	7	6	2	-	-
	Experiments	10	4	1	-	-
	Tests	3	7	2	3	-
	Photographs	7	3	2	1	2
	Diagrams and illustrations	11	1	-	-	3
	Reading level	5	4	4	2	-
Total for all Schools (N=105)	Subject-matter	24	49	15	11	4
	Experiments	53	33	8	9	2
	Tests	8	38	23	24	11
	Photographs	29	30	26	13	5
	Diagrams and illustrations	35	33	21	9	9
	Reading level	21	31	30	15	8

questionnaire, each student involved in the field testing of ASEP units responded to the unstructured part of the student questionnaire which included various open-ended questions. As this procedure led to the collection of sizable amounts of information, ASEP staff involved in collation of feedback needed to establish some quick and convenient method of summarising this information for use by the curriculum developers during rewriting. Table 4 illustrates how this was done by tabulating the frequency of common answers to each of six open-ended questions. The data in Table 4 are for the same sample of 105 students from seven classes involved in trialling the first version of "Charge".

Trial Students' General Comments

Trial students not only responded to the structured and open-ended questionnaire items discussed in the previous sections, but also were required to write down comments describing their general reactions to a unit as a whole. This information was collated by ASEP staff to produce a list of what were perceived to be the most salient comments made by students from each class involved in the field testing of a unit. In the case of the trial of the first version of "Charge", some examples of the general comments made by students are summarised in Table 5.

Results of Student Achievement Tests

As use of student achievement tests was an important aspect in the formative evaluation of ASEP units, achievement data are illustrated below the second trial of "Charge". Obtaining useful formative evaluative

TABLE 4. Summary of Frequent Student Answers to Open-Ended Questions

Question	Frequency	Answer
What did you like most about this unit?	29	Doing electroplating in Option 3
	29	Doing experiments
	15	Students work at their own pace
	12	Reading about Benjamin Franklin in Option 6
	8	Connecting circuits up
	7	You can find things out for yourself
	5	ASEP is informal
What did you dislike most about this unit?	16	Writing down results of experiments
	14	Giving verbal reports to the class
	9	Not having enough equipment for the whole class
	7	The fact that the class had already done some of the work earlier
	7	Experiments on plastic strips that wouldn't work
	5	The tests
What did you find the most difficult?	24	Nothing
	12	Getting some of the experiments to work
	9	The work on insulators
	6	Reading the booklets
	5	The section on ions
What can you do now that you couldn't do before?	52	Electroplating
	23	Make a battery
	14	Recharge a battery
	8	Make a spark
	5	Charge things electrically
	3	Work with electricity safely without being frightened
What do you know now that you didn't know before?	23	Electroplating
	17	Batteries
	12	History of Benjamin Franklin
	6	To avoid standing near pointed objects when lightning strikes
	5	Like charges repel but unlike charges attract.
	3	The finger is a conductor.
In what ways do you feel differently from before?	10	I'm not so scared of electricity now.
	5	I am beginning to like science more than I used to.
	4	I like to do science experiments at home.
	4	The importance of electricity in our lives
	2	I'm sure I don't want to be a science teacher.
	2	If I was the seventeenth son of a soapmaker (like Franklin), I could still be famous.

TABLE 5. Sample of Students' General Comments

School 1

The funnys were unfunny.

The unit was good because it had a lot of practical work.

This approach is better than being taught off the blackboard by the teacher.

The unit was a waste of time except for the copper plating.

The core was boring.

School 2

I think the options are good ideas but I would rather be learning science from the teacher himself.

Most girls aren't interested in this unit; mostly boys like this sort of work.

I think in cases where you have to set up a complicated experiment or even simple experiments, more diagrams are needed than were in the booklets.

I wish we could do more of this.

School 3

I enjoyed the experiments.

It was boring in places.

It was confusing in places.

School 4

At the beginning I liked the unit because it was an entirely new subject. But towards the end, I felt bored.

I feel this unit was a good introductory unit to electricity, but I think it should have gone into the unit further and it should have been longer.

I would like some clearer explanations about ions.

School 5

I felt that the unit I did was too long but I enjoyed it.

I found the experiments much too long, especially in the first unit. At the end it was terribly boring.

There is too much reading to do.

School 6

In some parts of the book there are parts that are too hard to understand.

Some of the pictures are not clear enough.

information from student achievement data, however, is not a simple matter. For example, the design of an appropriate and economical achievement test posed the difficulties described in Fraser (1973). Although some of the unit's important aims were affective and psychomotor, the need to use an economical paper-and-pencil instrument meant that it was easier to focus only to the unit's cognitive objectives. Furthermore, because ASEP units contain numerous sections of optional student material, it was necessary for a common achievement test to omit items measuring aims covered by optional sections and to restrict attention to objectives which were covered by the compulsory part of the unit or which were covered by several different options.

In an attempt to make interpretation of data more meaningful, use was made of a pretest as well as a posttest and of a control group as well as the ASEP group. By administering the same test prior to and after completion of the unit, it was possible to guage the changes in achievement which occurred during the time of studying "Charge". The purpose of the control group was to prevent attribution of changes to the curriculum when they might have been attributable to other variables, such as the mere passage of time, current cultural events, or familiarity gained from taking the same test twice.

Altogether 22 classes, each from a different school, were involved in the trialling of the second version of "Charge" in the six Australian states. Analyses were based, however, only on the 17 schools whose data had been returned in time for collation. Each of these schools provided two classes, one as an experimental class and one as a control class. This method of drawing two classes from the same school made the collection of control data easy to organise and quick, and also led to reasonable comparability between experimental and control groups. Of the 17 classes in each group, six were from New South Wales, five from Victoria, three

from Queensland, two from South Australia and one from Tasmania; one class was at the Year 7 level, seven were at the Year 8 level and nine were at the Year 9 level; and 10 classes were from government high schools, two from government technical schools, three from Catholic schools and two from independent non-Catholic schools. Also, in order to economise on testing time, a random sample of 10 students who had completed both the pretest and posttest were selected from each class for analysis. The total sample size was 170 for the experimental group and 170 for the control group.

Table 6 shows how achievement test data were collated (see Fraser, 1973). In particular, because of the need to obtain formative evaluative information to guide the rewriting of materials, students' total scores were not considered to be particularly relevant. Instead, student performance on individual items was examined in an attempt to identify specific objectives which were not being achieved well by students so that, in turn, material related to these aspects could be revised during the rewriting phase. The main descriptive information recorded in Table 6 is a statement of the objective measured by each item, together with the frequency of correct response shown separately for the experimental and control groups and for the pretest and posttest.

Despite the fact that pretest and control data are available, the interpretation of the results in Table 6 is still far from simple. At minimum, the experimental group should have exhibited a greater pretest-posttest improvement than the control group. For example, if statistical significance is taken as a guide, a minimum indication that the curriculum was somewhat effective in promoting a particular aim would be that the experimental group experienced a significant improvement in performance, whereas the control group did not.

TABLE 6. Differences Between Pretest and Posttest in Achievement on Individual Items

Item	Objective	Group	Frequency of Correct Response		Significance Test[a]
			Pre	Post	
1	To recognize situations in the environment where electric charge arises	ASEP	110	132	3.17**
		Control	110	119	1.32
2	To understand how to earth charged objects in the environment	ASEP	35	32	-0.48
		Control	22	33	2.12
3	To understand that like charges repel	ASEP	71	108	4.52***
		Control	65	86	3.00**
4	To understand that neutral bodies neither attract nor repel	ASEP	106	134	3.62**
		Control	102	114	1.81
5	To understand that unlike charges attract	ASEP	65	86	2.60**
		Control	59	64	0.63
6	To know how long ago Franklin worked with electricity	ASEP	93	109	2.03*
		Control	95	98	0.40
7	To explain an object's charge in terms of positive and negative charges	ASEP	67	100	4.16***
		Control	70	72	0.32
8	To understand that the sign of an object's charge depends on the material with which it is rubbed	ASEP	114	141	3.64***
		Control	118	115	-0.41
9	To understand that bodies rubbed together acquire equal and opposite charges	ASEP	30	40	1.48
		Control	34	41	1.07
10	To understand some attributes of a scientific model	ASEP	136	137	1.40
		Control	123	119	-0.53

[a] McNemar's z test.
* Significant at the 0.05 level
** Significant at the 0.01 level
*** Significant at the 0.001 level

Table 6 shows that this minimal criterion, in fact, was met for six items (namely, Items 1, 4, 5, 6, 7 and 8). On the other hand, this minimal criterion was not met for Items 2, 3, 9 and 10, thus suggesting that the parts of the unit dealing with the objectives measured by these latter items were unsuccessful in promoting achievement of intended aims.

It is arguable whether the degree of change observed for the items with statistically significant results was large enough to suggest that the unit was sufficiently successful in promoting a certain aim and, therefore, needed no revision to further enhance achievement. For example, the data in Table 5 for Item 1 showed that, among the ASEP group, the number of students correct increased from 110 to only 132 between pretesting and posttesting. Therefore the data in Table 5 illustrate that, despite the fact that some ASEP staff were hopeful that "hard data" about student achievement of intended aims might have provided a dependable foundation on which to base the rewriting of materials, the lack of clear criteria for interpreting such data made this ideal difficult to realise.

Visits to Trial Classes by ASEP Staff

Quite apart from the extensive written feedback obtained during formative evaluation from experts and students, substantial and useful evaluative information was obtained from classroom visits. In fact, during the field testing of the first trial version of each ASEP unit, numerous visits were made to trial schools by writers and other ASEP staff. During these visits, in-depth discussion with students and teachers, examination of written records of students' work, and informal observation provided valuable feedback information to complement and supplement that obtained using other methods. Close attention was paid to errors, inconsistencies and inadequacies in the materials as revealed by their use in the classroom.

ASEP's evaluation summary for the unit "Mice and Men" (ASEP, 1972a) lists some of the observations made by ASEP staff during the eight visits which were made to classes trialling this unit. Examples of some of the

observations which suggested areas likely to need attention during rewriting of materials were:

- Many students did not read the whole activity before commencing the practical work.
- The blank pages in the record book confused students.
- The black and white photographs on display had been ignored.
- Most students jumped sections of early work and moved into activities without properly reading instructions.

There are two noteworthy features of the use of classroom visits as a method of collecting formative evaluative information. First, observation and interview methods used during these visits were highly unstructured and spontaneous in comparison with much of the information collected through use of structured questionnaires. Second, as limited formal recording was done of information gleaned from these visits, there was less need to collate information than there was with other methods. Often curriculum developers would revise materials simply on their recollections of their own visits to school, or on the anecdotes and observations informally communicated to them by other ASEP staff who had made visits.

COLLATION AND USE OF EVALUATIVE INFORMATION

The collation of feedback information was an important part of formative evaluation procedures. Clerical assistants working in conjunction with ASEP's evaluation team were responsible for coordinating the final collation of all evaluation feedback into a form which was likely to be useful to the development team. During the national trials, however, part of the within-state collation of feedback was completed by coordinators of state trials before the information was returned to ASEP for overall collation.

Some data reduction was needed if the voluminous amount of information was to be reduced to a form which was manageable and useful when writers

were revising their units. In particular, as the tables in this chapter illustrate, data from structured questionnaires were aggregated to highlight overall trends. This aggregation of student data usually was carried out across the total sample, although some national trial data were collated separately for each state. However, in contrast to the way that individual responses to structured questionnaires were aggregated, all open-ended comments made by experts (external consultants, trial teachers, State Advisory Committees) were included in the collation of information. That is, it was thought that the person responsible for rewriting a particular unit should take cognisance of all comments made instead of a somewhat arbitrary subset of comments chosen by the staff involved in the collation task.

The size of the summaries of evaluative information for each ASEP unit tended to be quite substantial. For example, the inclusion of questionnaire data aggregated nationally or within each State, together with a complete listing of all open-ended comments made by experts, resulted in an evaluation summary of 29 single-spaced pages for the ASEP unit "Pushes and Pulls" and of 18 pages for "Life in Freshwater".

A notable feature of the evaluation summaries produced by ASEP staff for each unit was their inclusion of a comprehensive set of specific recommendations to be implemented when rewriting units. For example, the evaluation summary for the unit "Pushes and Pulls" (see ASEP, 1972b) included recommendations that:

- The name of the unit be changed to "Forces".
- The amount of reading in the unit be reduced.
- Summaries be included at the end of activities.
- The calibration of the student force-measurer against a standard scale be deleted as an activity.

- The photographs on pages 53 and 54 be interchanged.
- More space for student responses be allowed in the record book.
- The force-measurer be redesigned with a larger base to increase its stability.

UTILISATION OF EVALUATION RESULTS

An important question involves the extent to which the recommendations made in evaluation summaries were acted upon in the actual rewriting of materials. Cohen (1973) has provided an informative table for the ASEP unit "Mice and Men" showing what action, if any, was taken to accommodate feedback information. In fact, this table provides some good illustrations of ways in which information about specific weaknesses identified in materials through use of evaluation procedures influenced the rewriting of a unit. This table also shows that, for a variety of reasons, no action at all was taken during rewriting to cater for evaluative comments made.

It is difficult to comment either on the overall impact of ASEP's program of formative evaluation activities or on the relative utility of the various sources of evaluative information. One impression gained from interviewing different writers within ASEP was that different people found different sources of evaluation feedback differentially useful. Whereas some placed greatest weight on numerical information based upon consensus of the opinions obtained from large numbers of students or teachers, other ASEP writers preferred more intuitive judgements gleaned from casual observation in trial classes or informal talking with teachers and students. Similarly, writers differed when rewriting materials in terms of the amount of weight they placed on information obtained from outside consultants, teachers, students and State Advisory Committees.

The direct usefulness of formative evaluation feedback when rewriting units often appeared to be related to its specificity. The big advantage in highly specific information was that it was clear to writers exactly where changes were needed within a unit. On the other hand, information on experts' views about some general characteristic of the materials (e.g., the overall organisation of the unit) or data on student achievement of broad goals (e.g., comprehension of the concept of electric charge) did not pinpoint exactly what changes were needed to rectify a weakness. For example, one writer noted that feedback comments such as "I didn't like this section" were not uncommon and did little to guide the rewriting of a unit. ASEP writers often felt that evaluation efforts had identified important weaknesses that should be overcome, but had not provided information about what changes would be needed to surmount the problems.

This simple point about specificity has important implications for the planning of future formative evaluations. Whenever evaluation resources for any evaluation are likely to be limited, it may be preferable to concentrate efforts on the collection of specific information which yields clear implications for rewriting, rather than attempting to pinpoint more general problems whose solutions are far from obvious to writers attempting to revise materials. It is possible, also, that differences in specificity might explain why several writers at ASEP found comments written directly onto inspection copies of units much more useful in guiding rewriting than the aggregated results from general questionnaires or tests of student achievement of fairly broad objectives. Based on her experiences in the formative evaluation of Science 5/13 in the U.K., Harlen (1975) concluded that the results of children's achievement tests were of much less help in guiding the rewriting of materials than was information obtained from teacher questionnaires and classroom observation. In the case of the formative evaluation of ASEP, the specificity of items included in achievement tests often appeared to be a major determinant of their usefulness. That is, items testing specific achievement objectives

tended to yield some information which was useful in guiding unit rewriting, whereas items assessing general achievement objectives usually failed to produce suggestions useful when revising materials.

In an attempt to obtain the specific feedback which would be useful when rewriting units, ASEP's later evaluation procedures involved asking trial teachers and State Advisory Committees the following direct question: "If you were given the job of revising the unit, what changes would you make?" This question proved very successful because it elicited information directly relevant to the rewriting task at hand instead of general comments about strengths and weakness. Consequently, one simple but potentially useful inclusion in other future formative evaluations is a question which directly requests suggestions about desirable revisions.

The question of the effectiveness of different methods of formative evaluation cannot be divorced from questions of cost-effectiveness. That is, others involved in designing formative evaluation procedures are likely to be interested in finding out, not only what methods used by ASEP might have been more useful than others, but also which methods were very expensive and time-consuming and which were not. For example, in the case of ASEP, the use of student achievement testing proved sufficiently costly and time-consuming (especially in terms of test development and data collation time) that this approach to evaluation was abandoned some time before all units had undergone a second trial. Although the collation of student questionnaire data also was time-consuming, considerable economy was achieved by restricting attention to a sample of only 10 or 15 students from each class. In contrast, the method of asking various experts to provide their reactions by writing on the unit itself provided a relatively inexpensive method for obtaining valuable information which could be used directly without collation when writers were revising materials. Similarly, through visits to trial classes, developers were able economically to gain first-hand insights which could be translated

directly into action during the rewriting stage without the need for other staff to be involved in collecting and collating information.

PROBLEMS AND CONSTRAINTS

The main problem associated with conducting formative evaluation of ASEP materials and utilising evaluation results centred on shortages of time and funds. Since ASEP's main aim was to develop a certain number of units within a fixed budget, often there were difficulties in determining what proportion of the Project's total resources should be devoted to evaluation. For example, although it was the intention to subject units to two field trials, it proved necessary to exclude some from national trials towards the end of the Project when funds were running out. Also, since stringent production schedules had to be adhered to, there were problems in evolving methods which permitted evaluative feedback to be collected, collated and put to good use within tight rewriting deadlines. There is little doubt that time and financial stringencies meant that compromises had to be made in terms of the nature, amount and timing of the evaluation activities undertaken.

As ASEP's primary repsonsibility was the production of units within a fixed time frame, the time at which formative evaluative information became available was crucial. Clearly formative information could not guide rewriting unless it was available well before writing deadlines. In fact, these time stringencies led to the situation in which collation of information often had to be done before feedback had arrived from some trial schools and, in some instances towards the end of the Project, final rewriting was done without the benefit of any feedback information. Also, deadlines for revising units sometimes meant that the development team did not have sufficient time to utilise fully all the feedback information which was at their disposal. This experience highlighted the potential conflict that can arise between the need to satisfy production deadlines and to improve the educational merit of curriculum materials through making full use of all the formative evaluative information available.

Another problem which confronted curriculum writers was that feedback from different sources sometimes was inconsistent. For example, a unit might have appeared to be extremely well received in one state but not in another. Teachers could have been unhappy with a particular feature of a unit that was very popular with students. Also quite different reports were sometimes received from the teachers and students at different trial schools.

EXTENT TO WHICH EVALUATION MOVED TO RESEARCH

ASEP's formative evaluation efforts were conducted by internal Project staff and aimed to provide feedback useful in guiding the revision of curriculum materials. Consequently, this internal evaluation work tended not to move towards research. Nevertheless, external researchers and evaluators have completed an extensive body of research which is reviewed comprehensively by Fraser (1978a, b) and described briefly below.

Research into the impact of ASEP on a variety of student outcomes (e.g., inquiry skills, understanding of the nature of science, attitudes) suggested that students using ASEP materials performed neither better nor worse on most outcomes than students using alternative materials. For a measure of student enjoyment of science lessons, however, significant differences in favour of the ASEP group were observed (Fraser, 1979b; Fisher & Fraser, 1980a, b). Other research involving analyses of videotapes of science lessons has shown considerable similarity between the percentage of time spent on different activities in classrooms using different ASEP units, but marked differences between ASEP and conventional classrooms. For instance, the student was the source of activity for two-thirds of the time in ASEP classrooms compared with only one-fifth of the time in conventional classrooms. Also, when compared with conventional classrooms, ASEP classrooms were characterised by less fact-stating and a smaller proportion of lesson time spent with the whole class as the target of activity (Tisher & Power 1976; Power & Tisher, 1979). An extensive

questionnaire survey has indicated that teachers consider that the major advantages associated with using ASEP materials include opportunities for student choice and differential rates of student working, while common problems include student reading difficulties, organization of equipment, and assessment (Fraser & Northfield, 1981). Another series of studies involving students' perceptions of classroom climate has shown that, in comparison with students following conventional materials, students using ASEP materials perceived their classrooms as more individualised, more satisfying, and having better availability of resources (Fraser, 1979b).

It has been recognised that an important aspect of curriculum dissemination is the extent of purchase and use of curriculum materials (Welch, 1968). In fact, a recent major study by Owen (1978) has provided some interesting data about purchase and use of ASEP materials. For example, the amout of money spent by schools in purchasing ASEP materials between early 1974 and mid-1976 was found to be 1.4 million Australian dollars, an amount comparable to ASEP's total development budget. Furthermore, by the end of 1975, about two-thirds of all Australian schools owned at least some ASEP materials. The amount of purchase and use of ASEP materials however, was found to vary markedly in different Australian states and at different grade levels in the junior high school. Also the amount of usage of ASEP materials increased with the existence of advisory personnel who advocated ASEP's use and increased when school syllabuses were fairly consistent with ASEP's philosophy. Another particularly interesting finding emerging from Owen's study was that previous participation of a school's head of science department in the field trials of prototypes of ASEP units was a major factor influencing the amount of use of ASEP materials in a school.

CONCLUSION

Because the literature contains few retrospective accounts of formative (as distinct from summative) curriculum evaluations, this chapter portrays the comprehensive and varied formative evaluation activities associated with

the Australian Science Education Project (ASEP). It is hoped that this chapter will prove helpful to others embarking on formative evaluations through its provision of a detailed description of ASEP's evaluation approaches, its illustration of concrete examples of useful evaluation techniques and results, and its tentative conclusions about the relative usefulness of different techniques in guiding rewriting of materials.

Some specific but tentative conclusions based on experiences with ASEP's formative evaluation are summarised below:

1. Procedures of reflective evaluation involving a group of people vetting preliminary specifications and draft versions of curriculum materials is likely to lead to more economical use of resources by providing a basis for abandoning or improving materials prior to incurring the expense of production and field trials.
2. As different writers found various sources of formative evaluation information differentially useful, it may be preferable in future projects to use evaluation resources to generate more than one type of evaluative information.
3. As the usefulness of formative evaluation feedback appeared to be related to its specificity, it may be more useful in future formative evaluations to concentrate efforts on collecting specific information which yields clear guidance in rewriting than to attempt to pinpoint more general problems whose solutions are far from obvious to writers.
4. Certain methods of collecting evaluative information (e.g., student achievement testing) are likely to be more costly than others (e.g., visiting trial classrooms or having experts write comments onto copies of materials). In particular, visits to trial classes by writers involve economies since they involve little recording and collation of information.

5. Data on student achievement on individual test items are likely to be more useful in guiding the revision of materials than results on total test scores.
6. Use of both structured and unstructured questionaire items together is likely to produce information which is more useful than that obtained by either approach alone.
7. Because formative evaluations can generate large amounts of information, writers are likely to find collated feedback results (e.g., frequencies of common responses to open-ended questions) more useful than raw data when rewriting materials.
8. A conflict can arise between the need to satisfy production deadlines and to improve the educational merit of curriculum materials through making full use of all formative evaluative information available.

ACKNOWLEDGEMENT

Parts of this chapter are based on a report of ASEP's curriculum development processes being prepared in collaboration with Dr David Cohen of Macquarie University.

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PROBLEM SOLVING IN PHYSICS

J.A. Deacon

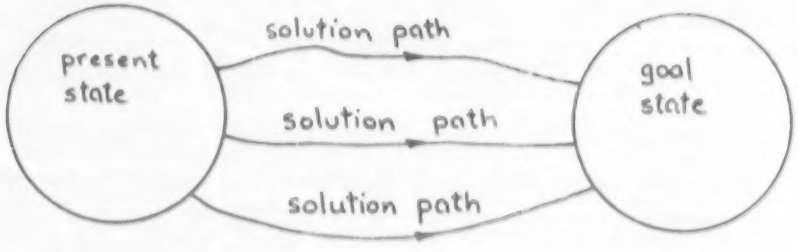
School of Physics and Geosciences
Western Australian Institute of Technology

INTRODUCTION

To explain the fundamental laws and principles of physics and to introduce the student to the use of these principles in the solution of numerical problems must be one of the aims of any physics course. Some might argue that education's highest goal is to prepare students to be problem solvers. Whether this be true or not there has been an increasing interest in problem solving techniques both in the learning and teaching aspect. Hill (1979) has provided an excellent annotated bibliography of some 300 references showing the increasing interest in problem solving over the last two decades. This trend seems likely to continue into the future.

At the outset it is worth defining some of the terms encountered in problem solving. The definition of what constitutes a problem varies slightly between authorities. A good model of a problem in general is that given by Rubinstein and Pfeiffer (1980). Their model is shown by Figure 1.

FIGURE 1:



The circle on the left represents the present state or condition or what is given. The circle on the right shows the desired state or goal state. The means by which the goal state is reached from the present state is

called the solution path or problem solving strategy. As shown in the figure, three alternative solution paths are possible for this problem.

A highly specified well known procedure such as a mathematical formula used for a limited class of problems is known as an algorithm. Problems which use algorithms are often referred to as exercises.

The solution of a problem in the most general sense involves what is known as a heuristic or heuristic frame. A heuristic may be regarded as a very general rule or set of rules for solving a wide variety of problems. The classic text on problem solving is that by Polya (1945). Polya's work concentrated mainly on mathematical probelms but it is sufficiently general to find application in the science area. Briefly, Polya's heuristic is as follows:

1. Understanding the problem
2. Devising a plan
3. Carrying out the plan
4. looking back

A number of investigators have developed heuristics for application in the science area.

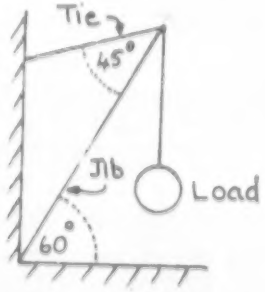
These include Woods (1975), Leibold (1976), Reif (1976), Mettes (1980) and Deacon (1980). Such heuristics are usually variations of that shown by Polya.

DESIGN

The problem solving methods of students in this investigation were taken from the worked scripts of the Western Australian Tertiary Admissions Examination in Physics for the year 1979. Only the solution of one problem in this examination paper was examined in detail.

The problem from the 1979 paper is as follows. (See Figure 2.)

FIGURE 2:



The diagram represents a jib crane. What are the forces in the jib and tie when the load is 1 tonne (10^3 kg)?

There are at least four different methods of solution to this problem.

Solution methods include:

1. Equating of torques or moments about suitable points.
2. Graphical means.
3. Use of Lamis Theorem or sine rule.
4. Resolution of forces.

Only the last method of solution was examined for it was considered to be the most powerful and general technique for problems of this type.

A table was drawn up so that an analysis of procedure in solution by the students could be examined.

The solution here was divided into 3 main parts :

1. Drawing the diagram with given information on it. — GIVEN
2. Adding to the diagram, features necessary for subsequent execution of formula or technique. — PLANNING
3. Execution of solution method by using suitable formulae. — EXECUTION

Tabel 1 was constructed to elicit this information and had the form shown.

TABLE 1:

STUDENT NO.	GIVEN					PLANNING				EXECUTION
	TIE	JIB	60^0	45^0	LOAD	10^4N	TIE ↙	JIB ↗	LOAD ↓	EQUATING OF FORCES
12345	✓	✓	✓	✓	✓	✓	✓	✓	✓	$F_J \sin 60^0 = F_T \sin 15^0 + 10^4$ $F_T \cos 15^0 = F_J \cos 60^0$

In the example above student 12345 according to the table has drawn the diagram and

1. marked on it tie, jib, load and angles 45^{o}, 60^{o}
2. shown a mass of 10^{3} kg as having a weight of 10^{4}N
3. marked the directions of tie, jib and load forces correctly
4. with suitable symbols for the forces, correctly equated components of forces in x and y directions.

For this study 124 student scripts were examined in detail. Of these 43 students successfully solved the problem and 81 were unsuccessful. A successful student was one who correctly set up the equations even if further arithmetic errors produced the wrong numerical result.

RESULTS AND DISCUSSION

The given and planning stage results are shown in the following table for the 43 successful students. (See Table 2.)

TABLE 2:

	GIVEN					PLANNING			
NO. OF STUDENTS	TIE	JIB	60^{o}	45^{o}	LOAD	10^{4}N	TIE ↙	JIB ↗	LOAD ↓
43	42	41	40	41	16	39	33	31	34
%	98	95	93	95	37	91	77	72	77
%	84					80			

The unsuccessful students had the following table. (See Table 3.)

TABLE 3:

	GIVEN					PLANNING			
NO. OF STUDENTS	TIE	JIB	60^{o}	45^{o}	LOAD	10^{4}N	TIE ↙	JIB ↗	LOAD ↓
81	54	55	76	76	27	67	10	9	48
%	67	68	94	94	33	83	12	11	59
%	71					41			

The final row in each table represents the percentage bits of information for the given and planning columns. For example in the last table (see Table 3)

$$54 + 55 + 76 + 76 + 27 = 288 \text{ bits of information.}$$

This represents $\frac{288}{5x81}$ or $\frac{288}{405}$ of the total possible i.e. 71%.

Comparison of the tables show

1. A higher percentage of successful students use the given information than the unsuccessful.

2. A markedly higher percentage of successful students showed forces in the jib and tie compared to the unsuccessful students.

It is worth noting here that a force well known by all students is that due to weight. Forces due to compression and tension were poorly understood by the less successful students.

Errors for th unsuccessful students were believed to be due to :

1. Failure to perceive that a body or particle was in equilibrium under the action of three forces.

2. Failure to show the direction of the three forces.

3. Confusion between resolution of forces and sides of triangles formed naturally by the diagram.

4. Failure to recognize that any single force must be always represented by two rectangular components not one if such resolution is used.

SOME TEST ITEMS

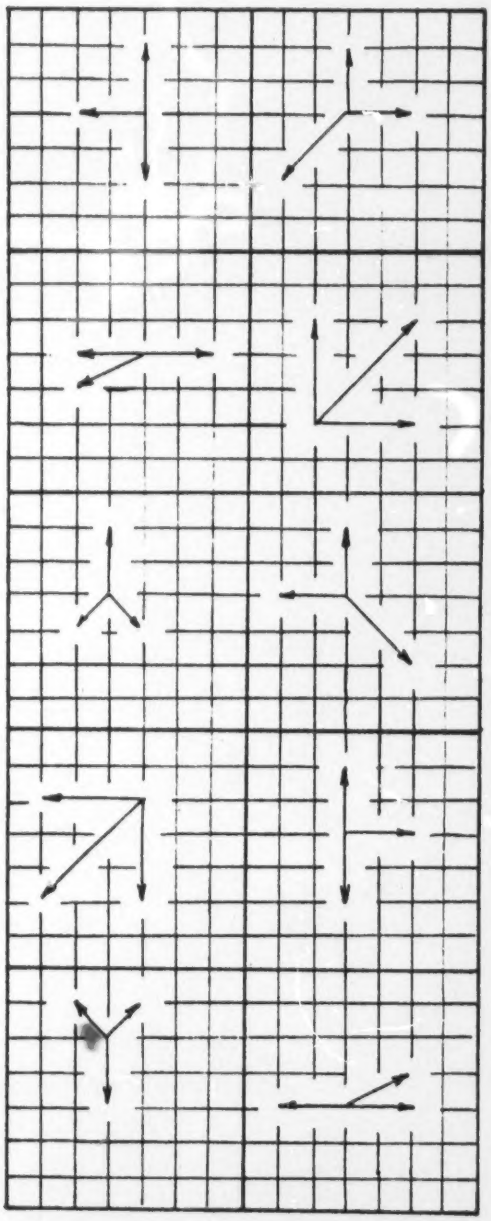
These errors initiated the setting of a test to examine knowledge and understanding of very basic concepts. The test was given to 61 students (ages 16 or 17 years) in two different schools. The time of year for the test was about 6 weeks prior to their final examination that is the Tertiary Admissions Examination.

Two of the test items were as follows.

TEST ITEM 1:

The diagrams each show 3 forces drawn to scale.
Tick (✓) the boxes where the forces are in equilibrium.
Cross (X) the boxes where the forces are not in equilibrium.
(See Figure 3.)

FIGURE 3:



TEST ITEM 2:

The word in the box names the body in static equilibrium.
Draw the three forces which keep this body in equilibrium.
Show the direction and point of intersection of the lines of action of these forces.
Also show the point of application of each force.

Note:

Each drawing involves an exploded diagram wherein the positions of contact have been artificially separated for clarity. (See Figures 4, 5.)

FIGURE 4:

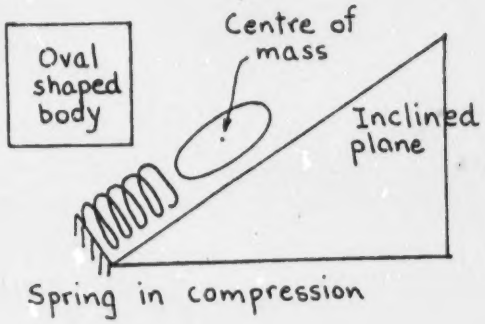
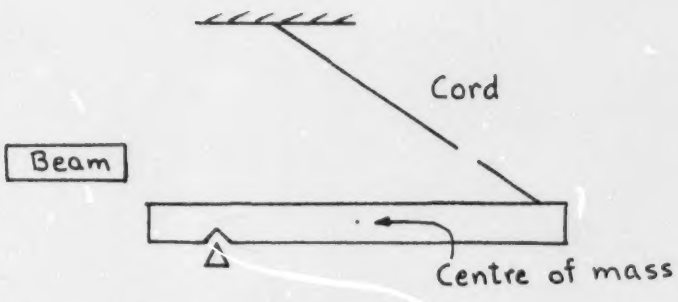


FIGURE 5:



Results

For test item 1 students showed a good understanding of equilibrium and overall attained a correct response of 92%.

For test item 2 only 52% of students were able to draw correctly the directions of 3 forces which would keep the isolated body in equilibrium. (Figure 4.)

For test item 2, 31% were able to show the force directions correctly. (Figure 5.)

CONCLUSION

Detailed examination of student answers to complex problems in tests and examinations can lead to identification of student misconceptions in basic understanding of physics principles. In may instances difficulties arise in the understanding (given) and planning stages of a problem. Before students commence the execution stage of the type of problem already described much practice should be given to exercises on isolating the body i.e. making a free body diagram and showing forces on it necessary for equilibrium.

The free body diagram is of great importance in mechanics and cannot be overstressed. The full procedure for drawing this diagram is well explained by Meriam (1975).

Class discussion on the development of a heuristic frame for a particular set of problems should be encouraged by the teacher or lecturer. To a greater or lesser degree all students have a heuristic frame for solving problems and in the opinion of the author all students should be trained to form their own heuristics if a sensible method of problem solving is to be gained.

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JAD:DH
22nd Sept. 1983.

PROGRAMME:

8.45 a.m. Registration: West Academic 2, Lecture Theatre

9.10 a.m. Welcome: Professor Mal Nairn, Deputy Vice-Chancellor

9.15 a.m. Symposium:

'The place of science in the curriculum'

Speakers: Dr. Denis Goodrum, Churchlands Campus, WAC
Mr. Ron Louden, Superintendent, W.A. Education Department
Professor Barry McGaw, Murdoch University

Chair: Dr. John de Laeter, W.A.I.T.

Each speaker will address the issue for approximately 15 minutes. About 40 minutes will be set aside for discussion.

10.45 a.m. Morning tea. (West Academic Staff Common Room, 2-21)

11.00 a.m. Concurrent session 1:

* A. *Students' Understanding of Chemical Equilibrium: A Report of Research in Progress*
Patrick J. Garnett and Mark W. Hackling

Chair: David Treagust

** B. *Measuring the Learning Environment in Elementary and Middle School Science Classrooms.*
Trevor W. Lacy

Chair: Bill Foulds

11.30 a.m. Concurrent session 2:

A. *The Effect of Inservice Training on Teacher Attitudes and Primary School Science Classroom Climates - An Interim Report*
Pauline Hutchinson

Chair: David Treagust

B. *Why Teach Science?*
Leonie J. Rennie

Chair: Bill Foulds

12.00 Concurrent session 3:

A. *Science Teaching Styles of Pre-service Primary School Teachers*
L. N. McKenna

Chair: Fred Deshon

B. *Time Available for Teaching: A Survey in Four West Australian Schools*
M.C. Crosbie

Chair: Muredach Dynan

12.30 Concurrent session 4:

A. *Primary Science Today*
John D. Rowe

Chair: Fred Deshon

B. *How Well Do Standard Piagetian Protocols Assess Aboriginal Children's Conservation Behaviour?*
David F. Treagust & Ross Hastie

Chair: Muredach Dynan

1.00 p.m. LUNCH (West Academic 2 Staff Common Room, 2-21)

2.00 p.m. Concurrent session 5:

A. *Enhancing Student Engagement in Upper Primary and Lower Secondary Science Activities*
Kenneth G. Tobin

Chair: Mark Hackling

B. *Beyond The Keller Plan*
Phillip Jennings

Chair: Muredach Dynan

2.30 p.m. Concurrent session 6:

A. *John Forrest National Park as an Ecological Study Area*
Bill Foulds and Judy Parsons

Chair: Mark Hackling

B. *Priorities for Computer Education in W.A.*
M.J. O'Loughlin and J. Luca

Chair: Jan Selsmark

3.00 p.m. Concurrent session 7:

A. *Techniques for Formative Evaluation of Science Curricula*
Barry J. Fraser

Chair: Leonie Rennie

B. *Problem Solving in Physics*
John Deacon

Chair: Muredach Dynan

3.30 p.m. AFTERNOON TEA (West Academic Staff Common Room, 2-21)

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* Session A: room 2-22

** Session B: room 2-27